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# USSR Report

ENGINEERING AND EQUIPMENT

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STABILITY OF INFINITELY WIDE TRIPLE-LAYER PANEL PROPELLED BY TRACKING FORCE

Yerevan IZVESTIYA AKADEMII NAUK ARMYANSKOY SSR: MEKHANIKA in Russian  
Vol 37, No 6, Nov-Dec 84 (manuscript received 11 Jan 83) pp 65-73

GRIGORYAN, N. B., Yerevan Polytechnic Institute imeni Karl Marx,  
Leninakan branch

[Abstract] The flight of an infinitely wide triple-layer panel driven by a uniformly distributed tangential compressive tracking force at a constant acceleration is analyzed as flutter of a nonconservative system. For stability analysis of such a system, the equations of small transverse vibrations are derived from the balance of forces on an element of unit width and infinitesimal length. Three different sets of boundary conditions are considered: 1) both panel edges free; 2) one panel edge free and the other panel edge constrained by an infinitely stiff diaphragm; 3) each panel edge constrained by an infinitely stiff diaphragm. Stability analysis of such systems by the dynamic method according to V. V. Bolotin involves determining the load dependence of the vibration frequency. The critical load under which the vibration amplitude begins to increase is determined, after the frequency equation has been obtained from the characteristic equations. The algorithm has been programmed for computer calculation and applied to panels with the flexural stiffness of both outer sheath layers varying over the  $0 \leq D \leq 1$  range. The two extreme cases  $D = 0$  and  $D = 1$  correspond, respectively, to a homogeneous single-sheath panel and a double-membrane panel. Panels are designed with  $D \leq 0.1$  for high stiffness-to-weight ratio, while a panel with  $D \geq 0.25$  can be treated as a double-layer one. When the filler is very stiff ( $k \geq 10$ ), then the two sheaths of a panel with both edges free behave like separate infinitely wide single-layer panels. Figures 6; references 12: 8 Russian, 4 Western.  
[188-2415]

## SUPERSONIC FLOW AROUND BLUNT PERFORATED SHIELDS

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 1, Jan-Feb 85 (manuscript received 26 Apr 83) pp 143-149

GUVERN'YUK, S. V., SAVINOV, K. G. and UL'YANOV, G. S., Moscow

[Abstract] Supersonic flow around circular and square metal shields at large angles of attack, within the  $75-90^\circ$  range, was studied experimentally in a wind tunnel with the Mach number varied over the  $N_M = 2.0-3.0$  range and the Reynolds number varied over the  $N_R = (2-4) \cdot 10^6$  range. The shields, originally  $10^{-2} \text{ m}^2$  in size, were perforated with identical circular holes reducing the total active surface area by 62.5%. The ratio of shield thickness to hole diameter was varied from 0.2 to 0.67, a ratio much smaller than 1 being simulated by countersinking the holes on the bottom side. The data are analyzed theoretically, with a model surface of discontinuity of parameters simulating a shield in a stream of an ideal perfect gas and with boundary conditions at that surface following from the integral laws of conservation. Transverse transfer of momentum is disregarded in the case of thin shields, to establish the dependence of the effective shield permeability on gas density, gas pressure, and normal stream velocity. On this basis is then solved the model problem of steady flow around a thin perforated disk perpendicular to the velocity vector of a supersonic gas stream, mainly for calculating the drag coefficient. Figures 5; references 10: 8 Russian, 2 Western.  
[202-2415]

## AERODYNAMIC INDUCTANCE OF SUBSONIC WIND TUNNELS WITH AXISYMMETRIC TEST ZONE

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian  
No 1, Jan-Feb 85 (manuscript received 19 Dec 83) pp 150-154

STARIKOV, O. Yu., Moscow

[Abstract] Subsonic flow of a nonviscous compressible gas around an axisymmetric impermeable body on the axis of a wind tunnel with an axisymmetric test zone is analyzed for an evaluation of the effect of wall inductance. The tunnel wall is surrounded by a constant-pressure medium, but the wall is made permeable by uniform perforation along the test zone. The corresponding boundary-value problem is linearized on the basis of sufficiently small velocity perturbations along the tunnel wall. The permeability of the tunnel wall is allowed to vary from  $R = 0$  corresponding to a solid wall to  $R = \infty$  corresponding to a "free" boundary surface between the gas flowing through the tunnel and the static gas of the constant-pressure ambient medium.

With the condition of zero velocity and zero velocity perturbation at infinity, the differential equation of flow with velocity and pressure perturbations is solvable by means of Fourier transformations. An inverse Fourier transformation yields the correction to the pressure coefficient accounting for the effect of wall inductance on the pressure distribution over the surface of the test model inside. Numerical calculations for a body of revolution generated by a curve  $r = 1/2\sqrt{x}(1 - x)$  ( $r$ - radius,  $x$ - axial coordinate) indicate for a wind velocity corresponding to the Mach number  $N_M = 0.6$  a wall permeability  $R_{opt} = 0.66$  will reduce the pressure correction and thus the distortion of the pressure profile around the body to zero. With a sufficiently large tunnel radius, relative to the body radius, any wall permeability within the  $0.56 < R < 0.77$  range will optimize the pressure profile at this particular wind velocity. The author thanks V. M. Neyland for discussion of the results. Figures 2; references 8: 5 Russian, 3 Western.  
[202-2415]

UDC 533.69.04

#### FLOW AROUND DELTA WINGS WITH BROKEN-LINE LEADING EDGES

Moscow IZVESTIYA AKADEMII NAUK SSSR: MEKHANIKA ZHIDKOSTI I GAZA in Russian No 1, Jan-Feb 85 (manuscript received 31 Aug 83) pp 171-175

SHVETS, A. I., Moscow

[Abstract] Two design concepts of delta wings for optimum performance at hypersonic velocities are compared on the basis of experimental data and their analytical evaluation. First are considered plain delta wings triangular in the plan view, with the dihedral angle ranging from  $\Lambda = 180^\circ$  in a flat triangular wing to  $\Lambda = 0^\circ$  in a completely folded one. Tests were performed on such wings with  $\Lambda = 180-150^\circ$  at angles of attack  $\alpha = -2-(+15)^\circ$  in a wind tunnel with the wind velocity varied over the Mach number  $N_M = 4-8$  range. The results indicate that reducing the dihedral angle decreases the lift coefficient only slightly when  $\alpha = 11^\circ$  but minimizes it and reduces the frontal drag coefficient by 50% within the  $\Lambda = 170-160^\circ$  range when  $\alpha = 7^\circ$ , with the maximum lift-to-drag ratio within the given range of  $\alpha$  being 20-30% higher at a  $\Lambda = 160^\circ$  wing than at a flat one. Next are considered delta wings with broken-line leading edges. Tests were performed on five models with a  $70^\circ$  sweepback angle of the nose and a  $50^\circ$  sweepback angle of the tail, all having the same 100 mm half-span in the plan view but each having a different dihedral angle  $\Lambda = 60, 100, 140, 180, 220^\circ$  respectively. Both the lift coefficient and the drag coefficient were measured in the wind tunnel at a wind velocity corresponding to Mach number  $N_M = 3$ , for determining their dependence and thus also that of the lift-to-drag ratio on the angle of attack. The aerodynamic characteristics of these wing models with the optimum dihedral angle were found to be better than those of flat wings with broken-line leading edges at hypersonic velocity, while they are known to be worse at subsonic velocities within the  $N_M = 0.5-0.9$  range. Figures 5; references 11: 10 Russian, 1 Western.  
[202-2415]

## APPLICATION OF AVERAGING METHOD TO PROBLEM OF CONTROL SYNTHESIS

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 23 Apr 82) pp 6-13

VYAZOVIK, A. P.

[Abstract] A scheme for nonlinear synthesis of control of systems containing slow and fast variables is developed on the basis of the fundamental constructs of the averaging method. The proposed method is used to solve the problem of controlling the movement of an aerodynamic object. In the approach employed, it is not required that the slow movements of the initial and averaged system be close during transients, which simplifies the formalization of the separation of motions. This results in a control synthesis scheme which is applicable to systems of standard form with a small parameter as well as systems which do not contain the small parameter as well as systems which do not contain the small parameter in explicit form. The synthesized control is modeled by computer for the launch of an aerodynamic object 22.5 km from the coordinate origin, with different angles between the velocity vector and the radius vector of the center of mass. The trajectories obtained behave such that the velocity vector first turns toward the coordinate origin, followed by near-rectilinear movement in the required direction. The integral curves are close to the plane defined by the initial velocity vector and to the coordinate origin. References 13 Russian. [49-6900]

## MOVEMENT OF FLEXIBLE WING AT SUPERSONIC VELOCITY UNDER INFLUENCE OF RANDOM GUST

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA: MATEMATIKA, MEKHANIKA, ASTRONOMIYA in Russian No 1, Jan-Mar 85 (manuscript received 22 Dec 82)  
pp 59-63

YERSHOV, B. A.

[Abstract] A study is made of the motion of an elastic wing of infinite span in an ideal compressible fluid under the action of a turbulent stream which is modeled by a random vertical gust. The unperturbed motion is the movement of a rigid wing at constant horizontal velocity greater than the speed of sound in the undisturbed stream. The perturbed motion is the deformation of the wing. The problem is reduced to an integro-differential equation in partial derivatives. The problem is one of connected aeroelasticity, such that the deformation of the elastic wing excited by the air stream changes the air stream itself. A previous work stated the basic problem related to

stability of elastic bodies in a potential gas stream. The present problem is determined by the wave equation for the excited velocity potential and the equation of oscillation of the infinite wing plate, related by the boundary condition on the wing. References: 2 Russian.  
[251-6508]

UDC: 532.525.2

#### OSCILLATIONS IN JET STRIKING BARRIER

Leningrad VESTNIK LENINGRADSKOGO UNIVERSITETA: MATEMATIKA, MEKhanika, ASTRONOMIYA in Russian No 1, Jan-Mar 85 (manuscript received 11 Oct 82)  
pp 63-69

KUZMINA, V. Ye.

[Abstract] A numerical study is presented of self-excited oscillations in a supersonic axisymmetrical jet striking an infinite flat barrier perpendicular to the axis of the jet. Information obtained in a numerical experiment concerning the flow in the area of interaction of the jet with the barrier is used to construct a physical model of the phenomenon. The jet striking the barrier is a self-excited oscillating system in which a periodic process of pulsations of parameters in the flow field is created by the constant source of energy, the gas mass exiting from the nozzle. The major supplement to the previously suggested physical model is the introduction of additional feedback through the peripheral gas flow. Figures 6; references: 3 Russian.  
[251-6508]

/9835

UDC 629.124.791.011.001.11:539.4

## TEMPERATURE FIELD IN HULLS OF ARCTIC VESSELS

Leningrad SUDOSTROYENIYE in Russian No 1, Jan 85 pp 9-10

ZIMNITSKIY, Yu. A., BOYTSOV, G. V. and NIKITIN, V. A.

[Abstract] An important problem in designing vessels for year-round operation in the Arctic Sea, especially ice-breaking, is calculation of temperature fields and thermal stresses in the hull. A rigorous solution of this problem for the ship hull as a whole is not feasible, due to the large dimensions and intricate shapes involved. A next best approach is proposed instead, namely subdividing the hull into elements and grouping them according to the conditions of heat transfer. Five different groups are distinguished on this basis: 1) structures exposed to sea air on all sides; 2) structures exposed to sea air outside and to room air inside; 3) structures exposed to sea water outside and to room air inside; 4) structures exposed to sea water on all sides; 5) structures within the water line region in contact with sea water, sea air, and room air simultaneously. A typical model is selected for each group, reduced to multilayer plates, beams, and hollow cylinders in whatever applicable configuration, and analyzed for heat balance under the corresponding boundary conditions. Since the room temperature is maintained fairly constant and the temperature of sea water varies only seasonally, wind temperature and velocity are the variable factors influencing the heat transfer intensity. Both vary slowly, and their changes are measured per hour so that the boundary conditions can be regarded everywhere as being constant. Owing to the high thermal conductivity of metal in the hull structures, moreover, the temperature field in each element can be regarded as steady. An evaluation of numerical data has yielded the semiempirical relation for the Nusselt number, referred to the characteristic dimension  $l$  of a structural element and the temperature  $t_f$  of water or air,  $Nu_{f,1} = 0.037 Re_{f,1}^{0.8} Pr_f^{0.43} (Pr_f/Pr_w)^{0.25}$  and thus for the heat transfer coefficient  $\alpha_{mean} = Nu_{f,1} k_f / l$  ( $Re_{f,1} > 4 \cdot 10^4$  Reynolds number for turbulent flow,  $Pr_f$  and  $Pr_w$  - Prandtl number at temperatures  $t_f$  and  $t_w$ ,  $k_f$  - thermal conductivity of water or air at temperature  $t_f$ . On the indoor side  $\alpha_2 = 8.3 \text{ W/(m}^2 \cdot ^\circ\text{C)}$  is reasonable. Typical design criteria are sea air temperature  $-50^\circ\text{C}$ , sea water temperature  $4^\circ\text{C}$ , room temperature  $0$  or  $20^\circ\text{C}$ , wind velocity  $20 \text{ m/s}$ , ship velocity  $2.5 \text{ m/s}$ . Figures 2; references:

4 Russian.

[187-2415]



## TOW RIG FOR ARCTIC ICEBREAKERS

Leningrad SUDOSTROYENIYE in Russian No 1, Jan 85 pp 14-16

STARSHINOV, V. A. and KUPERMAN, A. M.

[Abstract] Nuclear icebreakers of the "Leonid Brezhnev" (previously "Arktika") type are towed by the closing-in procedure. The tow rig on board of the vessel includes a winch with rope behind a garland, a Nikolayev turnbuckle between the winch rope and the "whisker" tow rope, and a tension damper. The damper has a hydraulic cylinder with carriage, a fixed guide and a retractable one, a thrust plate, a curb with knock-out pin, a pulley, a set of four rollers, and a set of air tanks for pneumatic drive of the carriage. The damper has been designed for given ranges of final cylinder pressure and tow rope tension, both depending linearly on the initial air reservoir pressure. Such a damper protects the bow end of the tugboat against impact loads when the icebreaker stalls, it increases the reliability and lengthens the service life of the tow rig, and thus improves its overall technical and economic performance indicators. Figures 5; references: 2 Russian. [187-2415]

UDC (629.12.037.4;629.12.037.11).001.11:539.4

## HIGHER RELIABILITY OF PROPELLER-SHAFT COUPLING

Leningrad SUDOSTROYENIYE in Russian No 1, Jan 85 pp 40-41

BELYAYEV, G. S.

[Abstract] The main deficiency of keying the propeller screw to the drive shaft is the high stress concentration along the keyway edges and the attendant low fatigue strength of such a coupling, another disadvantage being the necessary high precision with a large amount of manual labor required for manufacture and assembly. A promising remedy is use of an adhesive compound for sealing the clearance between propeller hub and shaft journal, to take up a part of the torsion load and thus reduce stresses on the mating surfaces so that precision can be relaxed, with an attendant labor saving. Such couplings were tested in model experiments on shaft simulators up to 100 mm in diameter and above 100 mm in diameter. Shaft, propeller hub, and key were made of grade-45 carbon steel, LMtsZh55-3-1 brass, and grade-50 carbon steel, respectively. The results of comparative fatigue tests without and with adhesive compound indicate the latter increases the life of a coupling typically from  $0.08 \cdot 10^6$  to  $3.5 \cdot 10^6$  cycles under a pressure of 1200 MPa and from  $0.7 \cdot 10^6$  to  $4.5 \cdot 10^6$  cycles under a pressure of 150 MPa. A new design of key and keyway has been developed for use of adhesive compound, to facilitate assembly and disassembly, with special slots for set screws for large shafts up to 300 mm in diameter. Figures 4. [187-2415]

TRAINING ENGINEERS FOR ROBOTIZED SHIPBUILDING

Leningrad SUDOSTROYENIYE in Russian No 2, Feb 85 pp 33-34

DOBROLENSKIY, V. P., DOGADIN, A. V., MATSKEVICH, V. D. and SOKOLOV, V. F.

[Abstract] At the Leningrad Institute of Shipbuilding, there has begun development of a curriculum in robotics for nautical engineers, to prepare them for the forthcoming introduction of industrial robots with the attendant new technology including flexible automatic production into the shipbuilding industry. This 0514.08 curriculum covers both theory and practice, study and apprenticeship, field work and research, classrooms and laboratories at the Robotics Center. The curriculum is broken down into three basic disciplines: 1) general education and general engineering; general shipbuilding; 3) mechanization and automation of shipbuilding operations, particularly welding. It includes fluidics and servomechanisms, control of automatic assembly lines, and integration of production processes. General courses have been modified, with more emphasis on components of navigation machinery and instruments as well as on hoisting and transporting equipment used in docks. The goal is to graduate adequately qualified engineers. This is achieved by requiring successful completion of robotization and shipbuilding projects, often on an empirical pioneering basis, as well as updating the qualifications of the teaching and scientific support staff. Figures 1; references: 2 Russian.

[204-2415]

/9835

PECULIARITIES OF EMERGENCY ELECTRIC SUPPLY SYSTEMS AT ROVNO AES

Kiev ENERGETIKA I ELEKTRIFIKATSIYA in Russian No 2, Apr-Jun 84 pp 5-6

[Article by A. N. Gudyma and A. M. Gorbatyuk, engineers, L'vovenergo Industrial Power Association, Rovno AES]

[Text] The first power generating facility of Rovno AES, which was connected into the power grid in December 1980, is the first of a series of standardized VVER-440 facilities with V-213 reactor. The use of technological nuclear safety systems on this facility ensures protection of personnel and the populace from outside and inside exposure, and security of the environment from pollution by radioactive materials within the limits of admissible norms in all emergency situations including the maximum credible accident involving rupture of the in-pile circuit.

The emergency electric supply system is a component part of the technological safety systems, and is intended for providing power to the drives of mechanisms that participate in emergency aftercooling of the reactor. The emergency electric supply systems include: diesel generators; 6 kV and 0.4 kV reliable supply systems; 6/0.4 kV transformers; uninterrupted supply facilities; DC panels; stepped-voltage automation.

The generating unit is provided with three self-contained reliable supply systems for voltages of 6 and 0.4 kV and DC, including autonomous power supplies. No mutual standby is provided between the three 6 kV and 0.4 kV reliable supply sections and the three diesel generators, as each of the safety systems is designed for 100% productivity (including electric supply).

The mechanisms for in-house needs of the AES with respect to reliability and uninterrupted electric supply are divided into three groups of consumers: I--those that permit brief interruption of supply for a fraction of a second; II--those that permit brief interruption of supply for up to 3 minutes, but must be reconnected after interruption of supply; III--those that do not place special demands on supply reliability.

In meeting the in-house needs of AES during startup of diesel generators, the 0.4 kV sections of reliability group I get supply from storage batteries via ABP inverters. When an emergency situation arises, the starting signal is sent independently to each diesel generator. The load is taken on by stages automatically. To prevent improper actions of operating personnel during an emergency, remote control of mechanisms is disabled for thirty minutes.

In emergency states involving a drop in voltage to less than 70% of nominal, the main job is speedy connection of the diesel generators to the 6 kV reliable supply sections. In the course of startup and adjustment work, the times from transmission of the starting pulse to the instant of connecting the diesel generators to the 6 kV sections in adjusting the speed regulators for the minimum idling speed of 400 rpm were 37, 28 and 36 s respectively for diesel generators of stations 1, 2 and 3. After readjusting the diesel generator speed regulators during preventive maintenance for a minimum idling speed of 640 rpm, the time characteristics of the diesel generators were 24, 23 and 22 s respectively, which will appreciably surpass the efficiency of technological safety systems.

The project calls for synchronous operation with the power grid for ABP inverters that supply the 0.4 kV consumers of reliability group I via storage batteries. The range of synchronous operation according to technical specifications for the manufacturing plant is  $50 \pm 0.5$  Hz. However, under the conditions of the considerable power shortage in energy-sharing modes of the Joint Power Grid of CEMA member nations and the USSR Unified Power Grid, there are frequent drops in frequency below 49.5 Hz, resulting in tripping of ABP inverters, disruption of supply to the reactor control systems, operation of the emergency protection system of the first kind, and emergency shutdown of the reactor. To prevent the operation of the ABP from depending on line frequency, synchronous operation of the inverters with the line has been eliminated and they are made to operate on their own output frequency. Circuit changes that ensure stable operation in a frequency range of  $49 \pm 0.5$  Hz have been made for the ABP source that covers the entire generating facility, supplies the computers, and permits only parallel operation of inverters with the line.

According to plan, when the relay protection devices operate for electrical shutdown of the generating unit, the breakers for the lead-ins of the working supply to the 6 kV sections are disconnected, and the automatic standby activation unit switches the entire in-house load of the generating facility to supply from the standby in-house transformer with power of 32 MVA. On the basis of calculations done in accordance with the procedure for the actual load of 6 kV in-house sections measured during operation of the generating facility at nominal power, and amounting to 2200 A for sections RA, and 1800 A for sections RB, the residual voltage across the 6 kV in-house buses will be 58% of nominal for sections RA, and 62% of nominal for sections RB, which is below the permissible level (65% of nominal). If the 330/110 kV coupling transformer has been removed for repair, or the reserve transformer has been preloaded, the residual voltage across the 6 kV in-house buses will be even lower. The necessary voltage level across the 6 kV sections is ensured when the in-house mechanisms are started from a 63 MVA standby transformer. Therefore, the planning organization is faced with the problem of replacing the existing 32 MVA transformer for in-house needs with one of greater power.

#### CONCLUSIONS

Experience in planning and adjustment work and service of the first generating unit at Rovno AES shows that the emergency electric supply systems require the most urgent attention to ensure high reliability and efficiency of technological safety systems.

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CSO: 1861/308

## UNIT FOR MEASURING THERMAL POWER OF VVER-440 REACTOR

Kiev ENERGETIKA I ELEKTRIFIKATSIYA in Russian No 2, Apr-Jun 84 pp 3-5

[Article by V. F. Vlasik, V. K. Rybalko, candidates of technical sciences, and A. A. Fedorov, engineer, Southern All-Union Heat Engineering Institute]

[Text] With increasing unit power of series-produced water-cooled water-moderated power reactors installed on 1000-MW generating facilities of AES, it is becoming especially urgent to solve the problem of continuously monitoring the actual thermal power of the reactor core.

Various methods are used to determine the thermal power of VVER reactors. These are based on measurements of radiation fields, thermal balance tests of nuclear steam-raising units, heat-engineering tests of generating facilities of the AES and so on.

The most effective method of determining the thermal power of VVER reactors is mathematical reduction of the heat balance of the nuclear steam-raising unit [1]. Repeated measurement of the thermal power through the secondary circuit yields good results when different methods are used with generalization of the resultant data. However, these methods are labor-intensive and require considerable time inputs for processing experimental data, making it difficult to use the results for on-line power monitoring.

In practice, the thermal power of the reactor core is determined from the average value of heating of the coolant in the reactor, assuming that there is little variation of its flowrate through the core. This is tenable as the admissible error of determining the thermal power of reactors on existing generating facilities of AES is accepted as 4%.

On-line monitoring of the thermal power of VVER-440 reactors is also done by standard radiation meters. However, these likewise have their disadvantages. Service experience on intracore monitoring with activation detectors has demonstrated considerable time lag, while direct-charge detectors are cumbersome and structurally complex. Moreover, the use of the latter necessitates intricate computational operations [2].

Analysis of existing methods of determining the thermal power of VVER reactors has shown that the lowest error is ensured by a method that contains elements of return heat balance and direct computation [3]. By using such a technique

in studies on existing generating units of AES, an empirical relation has been established between the amount of saturated steam produced by the steam generators, its pressure, average temperatures of the feed water sent to the boiler unit, and the power of the reactor core

$$W = \frac{\sum_{i=1}^{l=n} G_i - \sum_{j=1}^{j=m} G_j - \frac{5,6651 \cdot 10^{-6}}{m} \sum_{j=1}^{j=m} P_j - 0,1972 \sum_{i=1}^{l=n} \frac{G_i T_i}{\sum_{i=1}^{l=n} G_i} + 60,03}{7,8092 \cdot 10^{-4} \sum_{i=1}^{l=n} \frac{G_i T_i}{\sum_{i=1}^{l=n} G_i} + 0,3572}, \text{ MW, (1)}$$

where  $G_i$  is the flowrate of feed water of the  $i$ -th stream, kg/s;  $G_j$  is the scavenging flowrate of the  $j$ -th steam generator, kg/s;  $T_i$  is the temperature of the feed water of the  $i$ -th stream, °C;  $P_j$  is the saturated steam pressure in the  $j$ -th steam generator, Pa;  $m$  is the number of operating steam generators;  $n$  is the number of streams of feed water.

This relation is readily represented as a polynomial suitable for instrument realization

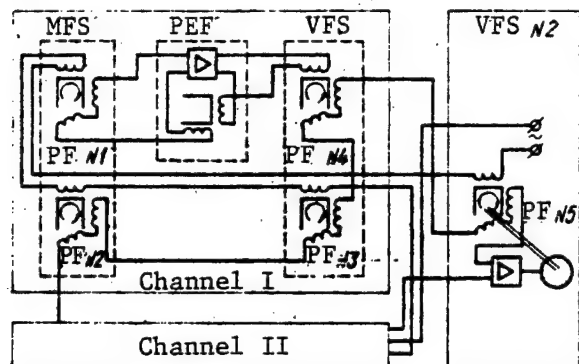
$$W = 2,166 (G_1 + G_2) - 0,885 (T_1 + T_2) - 1,05 \cdot 10^{-3} (G_1 T_1 + G_2 T_2) + 169,38n, \text{ MW. (2)}$$

Values of thermal power calculated by expression (2) were compared with experimental data of Soyuztekhnenergo obtained in the process of determining the technical-economic indices of generating units with VVER-440 reactors. The thermal powers of reactor cores in these experiments were determined with relative error of  $\pm 1\%$ .

At Southern All-Union Heat Engineering Institute, a thermal power meter has been developed for the VVER-440 reactor that realizes relation (2), based on series-produced Soviet instruments of the frequency-ferrodynamic system. It consists of two automatic self-recording bridges MFS-FFF, and three automatic-reading chart-recording secondary instruments VFS-FFF and two ferrodynamic transducers PEF.

The primary instruments are standard differential manometers and platinum resistance thermometers that are installed in the feedwater lines beyond the high-pressure heaters.

A schematic electric diagram of the thermal power meter is shown on the figure. The operation of multiplication is performed by ferrodynamic transducers PF N1,



Schematic diagram of thermal power meter for VVER-440

PEF and PF N4. A signal proportional to the feed water temperature is set by the output voltage of transducer PF N1. The angle of turn of the frame of transducer PF N4 is proportional to the flowrate of the feed water. A signal proportional to the product with consideration of a scaling factor is taken from the output of transducer PF N4. An analogous operation is done in the second channel of the instrument that operates with signals of the flowrate and temperature of the feed water in the second stream. The operation of algebraic summation is performed by ferromagnetic transducers PF N2, PF N4, PF N3 and analogous transducers in the second channel of the instrument. Signals proportional to terms with consideration of the scaling factors are taken from the output windings of the given transducers connected in a summation circuit.

The resultant signal, which is proportional to the thermal power of the reactor core, is fed to secondary instrument VFS N2, where it is measured by comparing with a signal generated by compensation transducer PF N5.

The output ferrodynamic transducers that performed mathematical operations were adjusted according to computed data. The thermal power meter for the VVER-440 reactor of the second generating unit of Armenian AES is installed on the modular control panel, and has been tested under industrial conditions. These tests have shown that the meter is in good operating condition, and its readings do not go beyond the limits of thermal power calculated by methods that are used in practice: This is confirmed as well by the fact that the calculated relative error for the case of using standard sensors of initial parameters was 2.6%. In this context, the relative discrepancies of the meter readings and data obtained by the corresponding techniques did not exceed 1.3%.

It was noted during the tests that the meter readings are not affected by changes in ambient temperature or vibration. In addition, it was learned that a further increase in the accuracy of measurements of the thermal power of the reactor depends on introducing automatic correction for the change in density of the feed water as its temperature varies over a wide range, and also on converting to an improved instrument base.

## CONCLUSIONS

A thermal power meter for the VVER-440 reactor has been developed, made and tested, that can be used for on-line monitoring and chart-recording of levels of thermal power in the reactor core. Further improvement of the meter will enable reliable on-the-spot monitoring of thermal power of nuclear steam-raising units with relative error of no more than 2%.

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## IMPROVEMENT OF AUTOMATIC CONTROL SYSTEMS FOR TECHNOLOGICAL PROCESSES IN NUCLEAR POWER PLANTS

Moscow TEPLOENERGETIKA in Russian No 8, Aug 84 pp 2-5

SHKABARDNYA, M. S., minister of instrumentation, automation equipment and control systems

[Abstract] Resolutions of the 26th CPSU Congress with regard to nuclear energy dealt principally with construction of 1000 and 1500 MW nuclear power plants, ATETs as well as AST, near large cities. Nuclear reactors now in operation include water-moderated water-cooled reactors, boiling-water graphite-moderated channel reactors, and fast neutron reactors. Development of automatic control systems for the technological processes in these NPPs can be viewed in terms of two stages. Until recently automatic control of reactors and turbines as well as of auxiliary equipment was done by means of relays and needle-indicator instruments on the basis of automated logic and with centralized data processing on computers for the station personnel. From now on, automatic control is to rely more heavily on computers and microprocessors. For this purpose; prototype information-computation systems such as the "Kompleks Uran" have already been installed in some NPPs (Novovoronezh, Rovno, Kola) during the 1980-81 period, whereupon the necessary software has been built up, while M-7000 computers were being replaced first with SM-2 and then with SM-2M or SM-1634 minicomputers. The Zaporozhye NPP, typically, is now using six SM-2M and four SM-1634 minicomputers with over 130 microprocessor complexes. High reliability requires decentralization and distribution of autonomous data gathering equipment, adequate redundancy in data processing hardware and software, and prioritization for direct digital functional-group control. This will be achieved by introduction of the "Kompleks Titan-2" information-computation system by 1985. An important ingredient is automated systems for scientific research with experimental test stands. These will facilitate construction and refinement of mathematical models, design of control and safety rods, rational selection of hardware for various reactor operating modes, debugging of functional-group control equipment, solution of problems pertaining to NPP trouble-shooting, and inspection of regulator hardware, particularly transducers and servomechanisms. Another important item is introduction of modern data display techniques, including color panels with industrial CRO

indicators for alphanumeric and graphic display of information, along with miniature switches, buttons, and other auxiliaries. The strategy of this development is designed to produce by the year 1990 a complete standard automatic control system for technological processes in all NPPs.  
[71-2415]

UDC 621.1.186.1

#### EXPERIMENTAL STUDY OF HYDRODYNAMICS OF IMMersed MESHES

Moscow TEPLOENERGETIKA in Russian No 8, Aug 84 pp 62-65

RYABOV, G. A., engineer (dissertator), and KOZLOV, Yu. V., candidate of technical sciences

[Abstract] The performance of meshes inside steam generators and separator drums in NPPs is analyzed on the basis of theoretical hydrodynamics and experimental data, such meshes being used for quenching the kinetic energy of steam and equalizing the load over evaporator surfaces. The efficiency of these devices, largely dependent on formation of a vapor cushion underneath, is determined on the basis of two critical velocities. One of them is the minimum vapor velocity below which steam jets flowing through mesh holes cease to be continuous. The other is the maximum water velocity at which a vapor cushion forms. The former is a function of water and vapor densities as well as on the hydraulic drag, the latter decreases with increasing pressure in a linear manner from 0.43 m/s to 0.16 m/s over the 3.5-7 MPa range. In the experiment were established the dependence of the vapor velocity in mesh holes on the critical pressure of incipient cushion formation as well as the dependence of the hydraulic drag in mesh holes and of the steam quality in the cushion on the vapor velocity underneath the mesh. Following a reconciliation with field data from the Kursk NPP and appropriate mesh modifications, semiempirical engineering formulas are recommended for separator design and performance calculations. Figures 5; tables 2; references: 11 Russian.  
[71-2415]

COOLING AND PURIFICATION OF AIR IN SEALED NUCLEAR POWER PLANT AREAS BY HIGH-THROUGHPUT AIR-WATER EJECTORS

Moscow TEPLOENERGETIKA in Russian No 7, Jul 85, pp 58-59

TURETSKIY, L. I., STOLYAROV, B. M., Candidate of Technical Sciences, BELEVICH, A. I., PUGACHEVA, T. F., YEVDOSHCHUK, R. M. and NOVIKOV, V. S., Engineers, All-Union Institute of Heat Engineering, Gidroproekt

[Abstract] A special recirculating ventilation system is used to cool the air which fills sealed areas created by the emergency localization system of a nuclear power plant, and to cleanse the air of radioactive aerosols and iodine under normal operating conditions. The system consists of two independent subsystems, one including high-capacity fans and water-air heat exchanges for cooling purposes, the other including high-pressure fans of significantly lower throughput, plus aerosol and iodine filters and other equipment for air purification. The equipment of the system must be capable of continuing operation after a loss-of-coolant accident [LOCA]. Low-head, high-throughput water-air ejectors have been used to create a system for cooling and purifying the air in sealed power plant spaces under both normal operating conditions and under LOCA conditions, the new system replacing the two systems traditionally used, a sprinkler system and a recirculating special ventilation system. A schematic diagram of the new dual-purpose system is presented. Figures 4.  
[325-6900]

/9835

UDC 621.311.22.002.51.681.325.2

SPECIFIC WAYS TO IMPROVE QUALITY OF CONTROL SYSTEM FOR POWER UNIT

Moscow TEPLOENERGETIKA in Russian No 8, Aug 84 pp 5-8

MIRONOV, V. D., doctor of technical sciences, GARBUZOV, V. G., engineer, ZHIDKOV, A. A., engineer, and SENYAGIN, Yu. V., candidate of technical sciences, All-Union Institute of Heat Engineering and Belorussian Institute of Power Engineering

[Abstract] Only a part of all automation equipment which has been designed for control of power units in power generating plants is actually used and must, moreover, be continuously inspected by station personnel. The two main reasons for this are an inadequate level of preparedness for automation and insufficiently high quality of the control system, characterized by steadily increasing complexity and decreasing reliability, as well as high cost and poor accessibility. In order to remedy this situation, experimental studies on a correct approach to the problem in the planning and design stage already had begun in the Soviet Union in the early nineteen sixties and have continued ever since. The basic structure of a control system in a power plant consists of five subsystems: automatic control, logic control, protective shielding, remote control, and data display. This structure has been modified by utilization of computer technology. First a single computer and then two computers have been introduced, an information processing computer and a control computer. The main problem is to economically ensure maximum reliability. With redundancy regarded as a tradeoff between cost of shutdown and cost of control hardware, a two-tier structure is so far found to be optimum. Here decentralized simple special-purpose equipment executes simple algorithms at the lower level, while the process control computer aids execution of complex algorithms at the upper level. Memory elements interface the two levels, for reducing the adverse economic consequences of computer failure. Integrating pulse transducers in automatic-regulation channels and binary storage devices in logic-control channels serve this purpose. Mini- and microcomputers are available for control at the upper level, specifically the SM-2M minicomputer, while individual AKESR [expansion not given] modules such as the RP4-U regulator are most suitable for control at the lower level. In a typical case of maneuvering with a process control computer, a 200 MW power unit under variable load conditions will reduce the total unpreparedness time over a 7500 hours operating period from 30 h to 2 h. Figures 4; references: 6 Russian.  
[71-2415]

## IMPROVING RELIABILITY OF MECHANICAL EQUIPMENT IN WATER-DEVELOPMENT WORKS

Moscow GIDROTEKHNIЧЕСКОYE STROITELSTVO in Russian No 2, Feb 85 pp 1-6

FREYSHIST, A. R., candidate of technical sciences, and MARTENSON, I. V., engineer

[Abstract] A qualitative reliability analysis of mechanical equipment for water-development works in three hydroelectric power plants of the Central Asian Hydro Project (Charvak, Nurek, Toktogul) reveals that reliability assurance must begin at the design stage on the basis of accurate data and precise calculations, taking into account that large and heavy structures are difficult to test in a laboratory. Reliability assurance will then proceed throughout both the manufacturing and installation stages, with consideration of the difficulties caused by dealing with relatively few standard items and many different items involved as well as of difficulties caused by the necessary assignment of narrow tolerances to large parts, whether made of steel or concrete. The final phase of reliability assurance is built into equipment operation in service. Experience from other hydroelectric power plants (Sayansk-Shusha, Kolyma, Saratov) indicates that reliability of mechanical equipment will be improved best by a higher degree of "redundancy", thorough more inspection, more comprehensive experimental evaluation, better means of repair or replacement, and use, wherever possible, of series-produced rather than custom-built parts in assemblies. While implementing these recommendations, one must strictly adhere to the All-Union Standard 34-03-584-83, especially with regard to locks. Figures 2; tables 1; references 12: 11 Russian, 1 Western. [203-2415]

## METHOD OF ESTIMATING RELIABILITY OF WATER-DEVELOPMENT WORKS

Moscow GIDROSTROITELSTVO in Russian No 2, Feb 85 pp 6-13

LYATKHER, V. M., doctor of technical sciences, professor, ZOLOTOV, L. A., candidate of technical sciences, IVASHCHENKO, I. N., candidate of technical sciences, and YANCHER, V. B., engineer

[Abstract] The problem of estimating the reliability of water-development works is considered from the standpoint of most economical design, and the "extreme states" method is modified so as to more correctly correspond to the true course of the failure process. Rather than being based on the absolute nonreliability indicator, which sharply peaks to unity but only when the probability of failure is already close to unity, an indicator is used which takes into account the properties of the structural materials in

terms of the probabilities of their various combinations as well as various loads in terms of the probabilities of their simultaneous action. The design criterion becomes, accordingly, the minimum sum of erection cost and damage or failure risk. These two elements are evaluated on the basis of available physical and mathematical models of water development works and their performance statistics covering the entire 1900-75 period. The design then proceeds on the assumption of deterministic soil and foundation characteristics, considering the "worst case" condition of seismic activity with available intensity and frequency projections. The procedure for design of water-development works based on reliability and cost tradeoff between technically adequate variants is demonstrated on spillways and cofferdams, with given numerical data. It is recommended that this procedure accompany standard procedures according to Construction Norms and Regulations, for design control and mutual verification of results. Figures 8; tables 5; references 12: 8 Russian, 4 Western (1 in Russian translation).  
[203-2415]

UDC 621.311.21.004.69

#### MODERNIZATION AND RECONSTRUCTION OF EQUIPMENT IN BRATSK HYDROELECTRIC POWER PLANT

Moscow GIDROTEKHNIЧЕСКОYE STROITELSTVO in Russian No 2, Feb 85 pp 42-44

USTINOV, I. F., director of Bratsk GES, distinguished power engineer of RSFSR

[Abstract] The first of the 18 hydroelectric turbine-generator sets in the Bratsk GES was put under load on 28 November 1961. The power plant with its present total capacity of  $18 \times 250 = 4500$  MW generates now electric energy at an average annual cost of 0.055 kopeck/(kW·h). The equipment is all Soviet-made: turbines built at the Leningrad Metal Works, generators built by the "Elektrosila" Scientific-Industrial Association, transformers and autotransformers built at the Zaporozhye Transformer Plant. Since 1966 the system has been powering 220 kV and 500 kV transmission lines, for which the transformer coils had been appropriately redesigned and dual air-oil cooling was added. Other modifications and improvements subsequently made include new generator stator coils with thermosetting insulation, forced lubrication of thrust bearings and reconstruction of the latter with elastic metal-plastic sliding segments for better reliability and faster repair or replacement, change from mercury-arc rectifiers to thyristors for excitation, addition of synchronous compensators for power factor correction, redesign of turbine impeller blades and air injection for better cavitation resistance, redesign of turbine guide vanes with polyethylene seals replacing rubber seals, replacement of VVN air circuit-breakers with VVB and VVD air circuit-breakers with higher current rating, and replacement of RLN-220 kV disconnect switches with RND-220 kV ones. Revisions now in progress include replacement of existing 200 kV and 500 kV cables with sealed ones, new cooling system for 750 kVA-500/220 kV autotransformers, and improvement of

the protective relaying-automation-telemechanical system. Noteworthy are thorough modernization and overhaul of the station lighting system and the fire protection system, the latter including oil traps for splash prevention and an asbestos-flour-cement-sand mix specially developed for filling cable passages through walls, also a new air cooling system and a new boiler room ventilation system. As a result of these modifications, no damage to equipment in the Bratsk GES has occurred during the last four years and the labor force in the plant could be reduced from 730 persons in 1970 to 507 persons in 1984.

[203-2415]

#### TURBINES PRODUCED BY 'TURBOATOM' PRODUCTION ASSOCIATION WITH HIGH HEATING LOAD FOR NUCLEAR POWER PLANTS AND NUCLEAR HEAT AND ELECTRIC POWER PLANTS

Moscow ENERGOMASHINOSTROYENIYE in Russian No 3, Mar 85 pp 46-47

BOROVSKIY, A. V., and USS, A. N., Engineers

[Abstract] Nuclear heat and electric power plants now planned in the USSR have a total heat capacity of 2,800 MW. The authors' association has achieved significant experience in the planning, adjustment and operation of condensation turbines with elevated heat output based on unregulated steam takeoff. The K-160-130 turbine produces 70 MW of heat, the K-300-240-80 MW, the K-220-44-93 MW, in all cases at least triple the heat output of the initial versions of these devices. The scientific and technical council has analyzed a technical plan for the K-1100-60/1500-4 turbine with a thermal load of 450 Gcal/hr, as well as a plan for the K-1070-60/1500-3 turbine with a thermal load of 1200 Gcal/hr. Production of these turbines will represent a new stage in the development of heat and power production equipment in the USSR.

[250-6508]

/9835

MANUFACTURE OF BEAMS OF NONUNIFORMLY AGING VISCOELASTIC MATERIAL IN MINIMUM PROCESSING TIME

Yerevan IZVESTIYA AKADEMII NAUK ARMYANSKOY SSR: MEKHANIKA in Russian Vol 37, No 6, Nov-Dec 84 (manuscript received 24 May 82) pp 48-62

DROZDOV, A. D., Moscow Institute of Automotive Mechanics

[Abstract] Manufacture of a beam of a nonuniformly aging viscoelastic material is treated as a problem of process optimization under the constraint of maximum allowable deflection of the beam axis. A plane state of strain and a constant modulus of momentary elasticity are assumed to characterize the beam material. The beam deflection will be measured some time after completion of the process, with either one end rigidly clamped and the other end free or with both ends hinged. The corresponding integral-differential equation for the deflection function is transformed so as to include the beam processing time instead of the beam length as variable, with the maximum acceptable processing time as a new constraint. The problem is solved by the method of penalty function. The result demonstrates that the processing rate for deflection-limited minimum processing time is a two-piecewise-constant, this optimum rate being the minimum possible in the first interval and the maximum possible in the second interval. The duality principle yields a companion theorem, that the time-limited processing rate for minimum beam deflection is also a two-piecewise-constant function with the optimum rate the minimum possible in the first interval and the maximum possible in the second interval. The optimization problem thus reduces to minimization of a single variable, on the basis of both theorems, and this has been done numerically for a typical beam of Portland alumina cement (4 m long, 0.3 m wide, 0.2 m thick). Figures 2; references: 9 Russian. [188-2415]



## INDUSTRIAL TECHNOLOGY

### INDUSTRIAL USE OF CHARGE-PARTICLE ACCELERATORS

Leningrad LENINGRADSKAYA PRAVDA in Russian 23 Oct 85 p 2

[Text] Beams of elementary particles accelerated to tremendous speeds and energies in accelerators have been put to work in metallurgy and in the textile and chemical industries. New applications of radiation technologies are being discussed at the Fifth All-Union Conference on the Employment of Charged-Particle Accelerators in the Economy, which opened yesterday at the House of Friendship and Peace with Peoples of Foreign Countries. Taking part in this conference, together with Soviet engineers and scientists, are specialists of Bulgaria, Hungary, the German Democratic Republic, Poland and Czechoslovakia.

"In a comparatively brief period of time, accelerator technology has earned deserved recognition in the most diverse branches of our country's industry and in agriculture and medicine," said A. A. Vasil'yev, head of an administration of the USSR State Committee on the Use of Atomic Energy, opening the conference. "The use of accelerators in industrial radiation-technology units has made it possible to put into production a number of products and materials with qualitatively new properties, to increase labor productivity substantially, to reduce pollution of the environment and to lower energy consumption."

Representatives of more than 100 organizations who are taking part in the conference are exchanging experience with the development of new types and modifications of accelerators, and they are discussing problems connected with the development of new-generation equipment and the introduction of revolutionary processes on a large scale.

FTD/SNAP/9835

CSO: 1861/25

GRANT LATHE WITH PLASMA-AIDED CUTTING ACTION

Kiev PRAVDA UKRAINY in Russian 10 Oct 85 p 2

[Article by Ye. Mzhen (Donetsk Oblast)]

[Text] The first lathe with plasma-aided cutting action has been built at the Kramatorsk Machine-Tool Building Association. This lathe can machine pieces up to 12 meters long and 2,000 millimeters in diameter, and weighing as much as 100 tons (with extra-hard surfaces).

A plasma arc heats up metal in the cutting zone in fractions of a second, and the cutting tool machines it easily. Productivity is heightened by almost eight times in the process. The cutting zone and the condition of the tool can be monitored on a television set.

The lathe has been set to the "Izhora Plant" association in Leningrad.

FTD/SNAP/9835

CSO: 1861/26

LIMITS OF HEAT TRANSFER INTENSIFICATION IN COMPACT HEAT EXCHANGERS

Moscow DOKLADY AKADEMII NAUK SSSR in Russian Vol 279, No 4, Dec 84  
(manuscript received 27 Jan 84) pp 888-891

SUBBOTIN, V. I., corresponding member, USSR Academy of Sciences,  
GORDEYEV, V. F., KHARITONOV, V. V. and PLAKSEYEV, A. A., Moscow Institute  
of Engineering Physics

[Abstract] Heat transfer in a heat exchanger of the simplest design, a plane porous layer between two solid plates, is analyzed on the basis of the two-dimensional two-temperatures model. The two-dimensional temperature field in the porous layer heated by a thermal flux from the sheath plates and cooled by a fluid filtering through it, is calculated as the solution to the corresponding system of Fourier equations of steady heat conduction and convection for the appropriate boundary conditions, assuming a negligible thermal conductivity of the fluid coolant in the direction of flow. The solution reveals that volume rather than surface heat transfer is the principal intensifiable component. Accordingly, four possible methods of heat transfer intensification are evaluated and their limits are compared: 1) increasing the dispersion of the porous layer; 2) use of liquid metals as coolant; 3) use of low-boiling or easily vaporizable liquids such as water and organic fluids as coolant; 4) artificial turbulization of the coolant flow. The porous layer can be designed with microchannels, holes, or slots, with sponge or brush structure, and can also be made of sintered metal fibers or powder. Figures 1; tables 2; references 6: 5 Russian, 1 Western.  
[155-2415]

COMPUTER-AIDED DESIGN OF TOOL ADJUSTMENTS

Moscow STANKI I INSTRUMENT in Russian No 2, Feb 85 pp 3-4

BASIN, Yu. Ya., KOROL, I. V. and ROZENTAL, P. L.

[Abstract] An algorithm has been devised and programmed for computer-aided design of tool adjustments, applicable to drilling, countersinking, boring, counterboring, reaming, and tapping of holes with machine tool. All basic information as well as blueprint and tool manufacturers' catalog data can be stored in the computer memory. The automatic design can be executed on a YeS-1022 computer with a 512 kbyte or larger memory and a YeS disk operating system, two magnetic disk storages and two magnetic tape storages, an alpha-numeric printer and a graph plotter. Figures 2.  
[194-2415]

COMPUTER-AIDED DEVELOPMENT OF CONTROL PROGRAMS AND OPERATION CHARTS FOR MACHINING ON LATHES WITH NUMERICAL CONTROL

Moscow STANKI I INSTRUMENT in Russian No 2, Feb 85 pp 4-6

ZHADOVICH, M. M. and SHEBANOV, V. G.

[Abstract] The design of control programs and operation charts for machining on lathes with computer numerical control has been added to the already existing but not yet complete TAU-TM computer-aided design system for control of technological processes. This particular lathe-oriented design routine, developed at the Minsk Branch of the State Planning, Technological and Experimental Institute for Organization of Machine-Tool and Tool Industry, involves sketching of contours in accordance with blueprints and machining requirements, filling and linewise punching of card decks with coded relevant geometrical and technological data, data input to the computer memory, data output with computed control program on punched tape, printing out control programs and operation charts, and graphically punched tape, printing out control programs and operation charts, and graphically displaying contours to be machined as well as the corresponding tool trajectories. The input language is the basic universal ESPS-TAU (Unified Programming of Machine Tools with Numerical Control). The data bank contains all relevant information on lathes, fixtures and accessories, also on interfacing with other machine tools. The logical unit here is a reference table listing all available design solutions from which the correct one is to be selected. The software, written in FORTRAN-4, is partitioned into functionally independent modules. The library of postprocessors for data readout in CLDATA language and implementation of the lathe control is already available for 25 different

lathe models. Special automatic graph plotters are also available for ensuring high control program accuracy and high machined contour fidelity. Figures 2; references: 2 Russian. [194-2415]

UDC 62-529.001.57:51

## OVERALL ORGANIZATION OF SOFTWARE FOR NUMERIC CONTROL MICROPROCESSORS

Moscow STANKI I INSTRUMENT in Russian No 2, Feb 85 pp 6-10

SOSOSNKIN, V. L.

[Abstract] The software for numerical control microprocessors is described first on the abstract level in terms of vectors and data categories, from which it is reduced to a graph and a flow chart for the computation process. Mixed rigid-dynamic planning of this process, essentially a sequential one with some quasi-parallelizing of steps, offers advantages over purely dynamic planning in that it requires less usage of the real-time operating system and simplifies prioritization of computation steps, on the one hand, while on the other its advantage over purely rigid planning is easier sequencing of numerical control tasks. The computation process is in turn controlled by programs such as "Translator ISO-7 bit", "Translator from User's Macro-language", "Translator from High-Level Language of Control Programs", and "Initial Loader", "Text Editor", "Debugger", "Communications Editor". An interpreter is used as command dispatching mechanism for execution of any one step in a given task. The design of a microprocessor for operation in numerical control proceeds in four stages: 1) draft design on the basis of mathematical model; 2) engineering design of data base and algorithmic structure; 3) practical design with complete documentation and interpretation; 4) design evaluation by testing, tracking, and correction. Figures 5; references 8: 5 Russian, 3 Western (2 in Russian translation). [194-2415]

## CLEARANCE STABILIZATION IN GAS STATIC BEARINGS OF SPINDLE ASSEMBLIES

Moscow STANKI I INSTRUMENT in Russian No 1, Jan 85 pp 11-12

MAKAROV, V. A.

[Abstract] An automatic clearance stabilization system for gas static bearings in spindle assemblies of machine tools is proposed, using not the pressure of lubricating compressed gas but rather the load on the bearing as the regulation parameter. While ideally the generated compensating force is equal to and directly opposes the nonsteady load such as the cutter force, in practice such an equilibrium requires elimination of the time or phase shift between the two forces. The magnitude of this phase shift determines the magnitude of deviation from equilibrium as well as the relation between the rate or frequency of load variation and the response speed of the compensating system. The transient characteristic of this system has been both analyzed and measured, the system including a set of inductive displacement transducers and electromagnetic displacement compensators mounted along the axis of spindle rotation pairwise symmetrically with respect to the transverse axis of the bearing housing. The bridge circuit for measurement and control is tuned when the bearing clearance is set at its nominal width. Figures 2; references: 4 Russian.

[194-2415]

## MACHINE TOOLS WITH NUMERICAL CONTROL, READJUSTABLE MACHINE TOOL MODULES AND SETS FOR FABRICATION OF LARGE PARTS

Moscow STANKI I INSTRUMENT in Russian No 1, Jan 85 pp 13-16

BESSOLTSEV, A. M., SKLYAROV, B. V. and POTAPOV, G. A.

[Abstract] A high-productivity set of heavy machine tools for fabrication of large parts has been developed at the Ulyanovsk Machine Tool Manufacturing Plant, by conversion of existing 6612/6620/6625/6640 UF2 machine tools from customized special-purpose to modular flexible configuration and from manual to numerical control with appropriate modernization of the equipment. As a result, there is now available the ASK-30 flexible readjustable automatic set of machine tools with computer control, capable of operating in two shifts. Its basic components are a statically rigid and dynamically stable support column, a milling-boring arbor with hydraulic speed changer, hydrostatic guide bushings, high-torque feed drives, crossarm drives with single d.c. motor, mechanisms for interchanging heads and tool bits, and a computer-based system for numerical control with selection of programs for custom machining processes. An SM1420 control computer is used for class CNC

numerical control, with the equipment laid out so as to ensure high precision as well as a high degree of versatility. Figures 3.  
[194-2415]

UDC 621.9.06-183.2-52

SPECIAL FEATURES AND FUNCTIONS OF AUTOMATIC CONTROL SYSTEMS FOR HEAVY-DUTY  
AND CUSTOM-BUILT MACHINE TOOLS

Moscow STANKI I INSTRUMENT in Russian No 1, Jan 85 pp 16-20

KOVAL, M. I.

[Abstract] Fabrication of large parts is characterized by a difficult procedure for blank positioning, a relatively large number of machining operations, and a relatively low production volume - all three factors contributing to a high unit manufacturing cost. Heavy-duty and custom-built machine tools for fabrication of such parts are necessarily designed to perform all operations with a single setting for all of the many tools involved. This is achieved by means of an automatic control system with special features and appropriate extra functional capabilities. Automatic compensation of errors in the positioning of subassemblies is based on the assumption that these errors are systematic and parametric, related in a definite way to some machine tool or automatic control parameter. Automatic regulation of the cutting process is essentially an adaptive control. Automatic inspection of tool bit for wear or breakage is nowadays done indirectly rather than directly, on the basis of indicators such as length of cutting time or geometrical changes in the cutting edge, or any process parameter functionally dependent on wear. Measurement of machined dimensions is done with multicoordinate (3-10) gauges using computer numerical control, this operation requiring large displacements (of the order of 10 m) with high precision (of the order of 0.01 mm) and often synchronous movement of several subassemblies so that a capability of processing a large number of signals (up to 500) must be there. Automatic measurement of tool bit dimensions and control of machining precision are best done by the test cutting method on a trial piece. Automatic trouble-shooting is among the last but not least special features and functions of the automatic control system. All the algorithms are programmed for microprocessors or microcomputers, with the software written preferably in expanded ISO higher-level language. Computer hardware includes general-purpose and special-purpose interfaces as well as spare storage arrays insertable into the communication channel to expand the memory capacity. Figures 3; references: 9 Russian.  
[194-2415]

AUTOMATIC ERROR COMPENSATION IN MEASURING SYSTEMS OF MACHINE TOOL WITH  
NUMERICAL CONTROL

Moscow STANKI I INSTRUMENT in Russian No 1, Jan 85 pp 20-22

KOVAL, M. I., KIM, Ye. N., KOROBA NOV, Yu. Ya. and LEYKUM, S. V.

[Abstract] Automatic compensation of errors in the measuring systems of a machine tool with numerical control is considered which first separates systematic error from random error on the basis of corresponding estimates and then subdivides the former into its cyclic intrastep component and the 10-15 times larger cumulative component attributable to manufacturing and alignment imprecision. Setting up for full compensation of the systematic error and minimization of the random error involve four procedures in the following sequence: 1) the primary dependence of measurement error on subassembly displacement is established experimentally in the machine tool; 2) this dependence is approximated and the approximation is stored in the microprocessor memory; 3) the corrections are continuously calculated by the program module in the numerical control computer on the basis of this approximation; 4) the corrections are made on displacements processed by the servomechanism drive. A ladder function with a uniform error step change is widely used for approximating the error-displacement relation, discreteness of changes in the measurement error making the approximation error variable rather than constant and proportional to the slope of this relation. Such an approximation as well as a more general and smoother piecewise-linear approximation were studied in simulation experiments, for optimum selection of discretization points as basis of the compensation program. Compensation of the total systematic error and of only its cumulative component alone was simulated on a YeS-1022 computer and directly on various machine tools, the latter being equipped with microprocessors for error compensation. Both software and hardware limitations were taken into account, as well as the particular features of a machine tool thus controlled. Figures 4; references: 2 Russian.

[194-2415]



## USE OF HYDROSTATIC BEARINGS WITH STRONG DAMPING IN SPINDLE ASSEMBLY OF BORING MACHINE

Moscow STANKI I INSTRUMENT in Russian No 1, Jan 85 pp 26-29

LAMM, V. Yu. and PAVLOV, V. A.

[Abstract] The spindle assembly for the model 22912N7F4 multipurpose machine tool developed and tested by the Leningrad Industrial Association for Machine Tool Construction imeni Ya. M. Sverdlov has two hydrostatic bearings, a front bearing 125 mm in diameter and a rear bearing 90 mm in diameter. The dynamic performance of these bearings under most severe conditions, maximum spindle torque of 1800 N·m at maximum speed of 3150 rpm is analyzed and compared with that of comparable adjustable-fit conical roller bearings and constant-fit cylindrical roller bearings. Calculations are based on two transfer functions characterizing, respectively, the mechanical structure and the hydraulic system of the bearing assembly. The resulting relations reveal that vibration damping within the critical frequency range depends on the stiffness of the structure and the viscous damping in it, as well as on the energy dissipation in both bearings - all functions of the vibration frequency. Improvement of vibration resistance without incurrence of additional energy losses is possible only by improving the hydrodynamic characteristics, rather than by increasing the viscous damping in the structure, or by reducing the stiffness of the structure but not below the level necessary for preventing contact between spindle and bearing surfaces. Two known practical means are examined comparatively for feasibility and effectiveness, namely the simple but less flexible boosting of the capacity of the hydraulic system by insertion of leakproof hollow storage cells into the pockets of the front bearing, and a more intricate but also more versatile corrective hydroservomechanism. A differential corrector with an additional negative feedback loop is recommended for the 22912N7F4 machine tool to be designed on the basis of the analytical procedure and applicable numerical data. Its advantages over conventional dynamic vibration absorbers are simplicity of design with the minimum possible number of moving parts and simplicity of connection into the system. Experimental evaluation in a model 2A622F2-1 test stand with contactless electromagnetic vibrator and measured amplitude-frequency characteristics of the prototype device indicate that, in order to maximize its effectiveness and extend its operational frequency range upward, it is necessary to reduce the inertia of the fluid in the hydraulic system and to increase the stiffness of the spindle arbor. Figures 5; references: 6 Russian.

[194-2415]

## HYDRAULIC AUTOMATION SYSTEMS FOR HEAVY-DUTY HIGH-PRECISION MACHINE TOOLS

Moscow STANKI I INSTRUMENT in Russian No 1, Jan 85 pp 30-32

YATSKEVICH, A. A. and PROKOPENKO, V. A.

[Abstract] Hydraulic systems for automatic control of metal-cutting machine tools contribute substantially to high productivity and high precision of machining operations such as boring. A differential system has been recently developed for heavy high-precision boring machines which the Leningrad Industrial Association for Machine Tool Construction imeni Ya. M. Sverdlov now produces. It is designed for balancing the vertically movable subassembly, in addition to automatically unloading the pilot bars interchanging tool bits as well as compensating deflections of the support column. It consists of two identical hydraulic cylinders mounted on both ends of the crossarm and connected through pipes to a reversible hydraulic machine (DG12-54AM pancake pump) with pressure regulator each. A distinctive features of this system is the variability of the pressure in each cylinder with the sum of both pressures remaining constant at a level which depends on and can be controlled on the basis of the balancing force. Remote control of the regulators is effected by signals from an electrohydraulic twin transducer whose control winding has been connected to a two-channel electric amplifier. The principal function of the balance control is to prevent movement of the balanced subassembly during faulty drop of pressure in any of the cylinders or excursion of the machine tool. A pair of disk brakes engages the respective nonself-braking lead screws of the subassembly drive during a fault by forward action of springs and releases them after clearance of a fault by reverse action of hydraulic pressure. Automatic unloading of the pilot bars on the sliding saddle ensures compensation for changes in the total weight over as wide as 4:1 range as a blank is placed on the table and subsequently machined. The servomechanism for compensating deflections of the support column includes a hydraulic amplifier bridge with a nozzle and a shutter, respectively, in two of its four arms and the measuring-converting devices in the other two. Compensation of deflection by means of this system maintains a machining precision within  $1.5 \mu\text{m}$  over a 1.5 kN range of load variation. Figures 4; references: 4 Russian.

[194-2415]

UDC 658.015.12.011.56.621.865.8

SUBSYSTEM 'SELECTION OF INDUSTRIAL ROBOT' OF COMPUTER-AIDED DESIGN SYSTEM

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 84 pp 3-5

DUDKO, Ye. A., NAYDEK, A. V. and YAMPOLSKIY, L. S.

[Abstract] A subsystem "selection of industrial robot" has been added to the computer-aided design system for design of robotic technological complexes. The data base contains 70 relevant characteristics, including dimensions and capabilities of a robot and its principal components, properly categorized and sequenced according to All-Union State Standard 25378-82, written in PL/1 using a binary code. The algorithm of selection is a straight sequential one with only two feedback loops, into which three sets of data, namely load data, special requirements, and applicable robot parameters are entered at three respective points along the computation process. Figures 1; tables 2. [195-2415]

UDC 621.941.28

TRENDS IN DEVELOPMENT OF TURRET-TYPE MACHINE TOOLS FOR UP TO 2.5 m MACHINING RADIUS

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 84 pp 5-8

SAFRONOVICH, A. A.

[Abstract] The basic configuration of a vertical machine tool is that of a horizontal cantilever crossarm vertically movable along its support rack-column holding a jig horizontally movable along this crossarm with a tool head both rotatable and vertically movable in the jig above a rotatable table with sectoral face plates horizontally movable in the saddle perpendicularly to the crossarm. A major modification for machining parts with a radius larger than 1.5 m, up to 2.5 m, is adding movability of the table with face plates parallel to the crossarm above, either closer to or farther away from the support column. The thus modified machine tool occupies 1.5 less floor area than a double-column one and weighs only half as much, thus being hardly replaceable for custom and small-scale production. Higher machining precision is achieved by various modifications such as in the design of the face plates, use of high-class roller bearings instead of ball bearings, wider and finer tool speed regulation by use of a d.c. motor with thyristor control and multistep gear switching. Higher productivity is achieved by introduction of multipurpose machine tool turrets for drilling and boring as well as milling in addition to turning without resetting of the machined part, with capability for increased intricacy of contour shaping, with reduction of idle time by automatic and thus faster interchanging of tool heads with tool bits mounted on a disk or a drum rotating on a vertical shaft, in

cartridges from which they are dropped into position for cutting by special plunger mechanisms. Other improvements in overall machine tool characteristics are built into their electric and hydraulic systems including numerical control, also into the protection of machined surfaces against chips, dust, and lubricant-coolant fluid. Figures 4; references: 3 Russian. [195-2415]

UDC 621.941.28-183.2

#### DYNAMICS OF HEAVY-DUTY TURRET-TYPE MACHINE TOOLS

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 84 pp 8-12

KAMINSKAYA, V. V.

[Abstract] A method of analyzing the dynamics of machine tools has been developed at the Experimental Scientific Research Institute of Metal-Cutting Machine Tools for application to single-column heavy-duty turret-type machine tools with face plates 1600 mm in diameter as well as to double-column ones produced at the Kolomna Heavy-Duty Machine Tool Manufacturing Plant with face plates 3200 mm in diameter and at the Krasnodar Machine Tool Manufacturing Plant imeni G. M. Sedin with face plates 4000 mm in diameter. The method involves pickup and measurement of all vibration modes within the critical 35-200 Hz range in the three principal orthogonal planes, with particular emphasis on self-excited modes and resonances, followed by calculation of their spectral density and amplitude-frequency responses on the basis of the dynamic model of the machine too, correlation of static and dynamic deflections as well as their dependence on the compliance of the support structure, correlation of experimental and theoretical data, and finally stability analysis. The results of a study made on such machine tools suggest certain design recommendations. These are that the support structure is generally more rigid with use of hydrostatic rather than sliding jigs and that in the case of sliding jigs a rectangular slider with a 0.7-0.8 height-to-width ratio is preferable to a square or octagonal one. Different vibration modes are dominant in single-column machine tools and in double column machine tools, namely torsional and some flexural modes within a narrow frequency range in the former, torsional and antisymmetric modes within a wide frequency band in the latter. The dynamic rigidity of double-column machine tools in the low-frequency range is determined principally by the stiffness of the columns and by their mounting in the foundation. The vibration resistance does not significantly depend on the crossarm design in the Kolomna machine tools, but does depend on it in the Krasnodar machine tools to the extent that a redesign of the rear window has improved the vibration resistance by up to 50%. Figures 6; references: 6 Russian. [195-2415]

## HYDROSTATIC SPINDLE BEARINGS IN HEAVY-DUTY BORING MACHINES

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 84 pp 12-15

BUSHUYEV, V. V., TSYUNOV, O. K. and FEDOROV, A. I.

[Abstract] The performance of hydrostatic bearings for spindles in heavy-duty boring machines is evaluated on the basis of experimental tests and measurements made in a model 2N636 machine tool at the Kolomna plant of the Industrial Association of Machine Tool Manufacture. The effectiveness of feeding through multifold throttles with simultaneous resistance regulation in each, according to the Kolomna design, is comparable with that of pump-to-pocket feed (Schliss-Froriep GmbH, FRG) and with that of throttle feed through capillary tubes with fixed resistance (Innse S.P.A., Italy). Deflection of the retaining ring and oil temperature in the front bearing, indicators of stability, were measured over a 6 h period at spindle speeds over the normal 6-1600 rpm range and found not to exceed allowable levels. The change of pressure in the bearing pocket was found to increase linearly with the peripheral velocity, at a rate decreasing with larger radial clearance between the spindle and the elliptical bushing. A comparison with a conventional rolling bearing reveals that the frictional power loss in a hydrostatic bearing is lower at speeds up to 1200 rpm but can become higher at speeds above 1200 rpm so that forced cooling may be necessary. Static and dynamic deflections of the retaining ring, characterizing respectively static and dynamic stiffness of the bearing, are smallest with multithrottle adjustable-resistance feed. Such a feed system ensures also better vibration characteristics, with minimum peaking of the amplitude within the critical 10-20 Hz frequency range, and a much softer transient than a rolling bearing. On the basis of these results are established design criteria for hydrostatic bearings, applicable to rough and fine boring as well as milling of cast iron or steel parts. Figures 4; tables 3; references 4: 3 Russian, 1 Western.

[195-2415]

## HYDROSTATIC GUIDES FOR TRANSLATORY MOTION IN HEAVY-DUTY TURRET LATHES

Moscow STANKI I INSTRUMENT in Russian No 12, Dec 84 pp 15-16

TSYUNOV, O. K., BUSHUYEV, V. V. and FEDOROV, A. I.

[Abstract] The performance of hydrostatic guides for heavy-duty turret lathes is evaluated on the basis of experimental tests and measurements made at the Kolomna plant of the Industrial Association for Machine Tool Manufacture. The slider sealed by cuffs so as to close a 2-4 mm clearance and oil pouring alongside between slider and rails into a pan. The jigs were

loaded statically and dynamically in the three principal orthogonal directions of slider displacement coordinates. Strains and displacements of the guide rails as functions of the load in each direction, and the amplitude-frequency responses of rail vibrations were all measured under two different feed conditions, directly from pump and through regulating throttles. In both cases the oil layer was found to be less dynamically than statically compliant, and no overregulation was found to occur during the transient period after disengagement of the iron bar. The overall performance of the guide rails was found to remain stable over wide ranges of oil viscosity and compressibility, damping, and throttling ratio. Figures 4. [195-2415]

UDC 621.9.06-86

#### INERTIAL DRIVE IN METAL-CUTTING MACHINE TOOLS

Moscow STANKI I INSTRUMENT in Russian No 11, Nov 84 pp 11-13

SHIMANOVICH, M. A.

[Abstract] A special spindle drive has been developed at the Moscow Institute of Machine Tools for control of the metal-cutting process so as to ensure highest possible machining precision. A main power drive is used for starting and stopping the spindle as well as for rough machining, while a much less powerful auxiliary drive is used for fine machining and checking. Changeover from one drive to the other during the process cycle is facilitated by a set of elastic or contactless couplings. Such a system makes precise spindle rotation and reduction of surface roughness to within the 0.02-0.05  $\mu\text{m}$  range feasible, but still does not completely eliminate perturbations. This is achieved by temporarily disconnecting the spindle from the drive and operating with the kinetic energy stored in the spindle. Addition of a flywheel will increase the total amount of kinetic energy available, especially when friction losses in the bearings and air drag at high spindle speed are kept at a low level. Slowdown of the spindle during coasting helps stabilize the cutting rate, especially in machining flat or intricate end faces from the minimum radius up. The clutch which connects the spindle to the power drive for acceleration and energy storage has been designed for machine tools with the simplest and crudest type of drive, which is a squirrel-cage induction motor. The starting and acceleration characteristics of a wound-rotor induction motor or a direct-current motor are better, but the brushes must be lifted by an electromagnetically actuated spring mechanism, and this source of perturbations is thus removed during machining with the spindle coasting. The machining process with such a drive has been evaluated theoretically and experimentally, the results indicating a satisfactory performance of the drive in superhigh-precision machining with diamond tool bits. Replacement of air in the machining space with a low-viscosity medium such as butane and, even more so, machining under vacuum either reduces the drag losses and thus makes more

kinetic energy available or allows machining to a larger radius with the kinetic energy available. The principle is applicable to both translatory and rotary reciprocating motion. Figures 3; references: 8 Russian (all patent disclosures).  
[195-2415]

UDC 621.9.06-529-589-585

#### OPTIMUM STRUCTURE OF FEED DRIVES FOR MACHINE TOOLS WITH NUMERICAL CONTROL

Moscow STANKI I INSTRUMENT in Russian No 11, Nov 84 pp 13-15

LEVIN, A. I.

[Abstract] The structure of feed drives for machine tools with numerical control is optimized with respect to dynamic performance according to the theory of feedback control. The servomechanism consists of a d.c. motor characterized by two time constants, an electromechanical one and an electromagnetic one, with speed regulator and current regulator. The control structure includes three mechanical feedback loops (angular displacement, angular velocity, torque) and two electrical feedback loops (armature current, counter-emf). For a servomechanism with the optimum open-loop transfer function, which is a second-order one, optimization of the control system involves matching the transient characteristics of the electric motor with those of the motion converting mechanism, minimizing the effect of insensitivity and saturation zones in the velocity feedback loop on the transient characteristics of the servomotor, and either minimizing or maximizing the servomotor sensitivity to fluctuations of the cutting force depending on whether maximum accuracy or maximum damping is required. Figures 3; references: 6 Russian.  
[195-2415]

UDC 62-83-5:681.3.06

#### ALGORITHM OF SPEED REGULATION FOR DIGITAL ELECTRIC DRIVES

Moscow STANKI I INSTRUMENT in Russian No 11, Nov 84 pp 15-16

KOVALEV, S. P.

[Abstract] An algorithm of speed regulation has been developed at the Leningrad Institute of Electrical Engineering imeni V. I. Ulyanov, especially for digital electric drives used in winding machines. The regulator on the basis of this algorithm is the digital analog of a proportional-integral-differential one, with no need for the integral component of the control signal during transient periods to be calculated when the acceleration is maximum. Advance current limiting for transient suppression occurs in the



thyristor circuit, where the control signal is determined by the instantaneous motor speed and the motor overload capacity. The algorithm provides in separate branches for regenerative braking, startup at maximum acceleration, and overspeed reduction with anticipatory "flagging" of the respective control signals. The algorithm includes the ARCOS subroutine for computing the thyristor firing angle  $\alpha = \cos^{-1} N_y / N_{y0}$  (code of control signal). The algorithm has been programmed in "Elektronika-60" microcomputer language and, with use of multiplication hardware, occupies 512 memory cells. Execution of the program for a PBST-22 servomotor with Y-connected 3- $\emptyset$  thyristor circuit is completed in 710  $\mu$ s, the ARCOS subroutine requiring 340  $\mu$ s. Figures 2; references: 1 Russian. [195-2415]

UDC 62-82

#### NEW PROTECTIVE DEVICES FOR HYDRAULIC CYLINDER PISTONS

Moscow STANKI I INSTRUMENT in Russian No 11, Nov 84 pp 27-29

BURENIN, V. V.

[Abstract] Twelve new protective devices for hydraulic cylinder pistons are described: five decontaminators, two bellows, and five protective jackets. The decontaminator according to Czechoslovak Patent No. 190,914 is a stack of slotted metal spring washers. The decontaminator according to U.S. Patent No. 4,261,583 includes an elastomer seal; another version developed by West Pneumatics Co (USA) combines copper-beryllium with an elastomer. The decontaminator developed by Fluid Power Co (USA) is a V-form pair of scraping cuffs made of wear-resistant polyurethane for pistons 5-330 mm in diameter. The decontaminator developed by Texacone Co. According to U.S. Patent No. 4,179,856 is a split plastic hood which has a porous elastic rubber lining with abrasive cloth on the inside for rust removal. The bellows developed by Witzen GmbH (FRG) is made of a special alloy which remains elastic and reliable at ambient temperatures up to 900°C. The bellows according to U.S. Patent No. 4,287,814 is supported inside by three movable guide bars which limit its extension and compression. The protective jacket developed by Alfa Romeo S.P.A. (Italy) according to the French patent disclosure No. 8,121,071 is a corrugated conical one made of neoprene or another elastic material without fasteners. The protective jacket according to U.S. Patent No. 4,253,675 is a cuffed membrane made of a cloth-reinforced elastomer. The protective jacket developed by Tokico Ltd. (Japan) according to U.S. patent No. 4,304,416 is made of an elastomer with a reinforcing metal sleeve for short-stroke pistons. The protective jacket according to French patent disclosure No. 7,900,455 is a corrugated cylindrical one made of an elastic material. The protective jacket according to British patent disclosure No. 2,062,132 is a  $\omega$ -form bellows made of a metal or plastic material, characterized by exceptionally long life. Figures 7; references 12: 1 Czechoslovak, 11 Western. [195-2415]



## METHOD OF INCREASING WEAR RESISTANCE AND FATIGUE STRENGTH OF PARTS MACHINED BY GRINDING

Moscow STANKI I INSTRUMENT in Russian No 10, Oct 84 pp 30-31

BUTENKO, V. I. and KULINSKIY, A. D.

[Abstract] Conventional postgrinding surface treatment by plastic deformation and low-temperature stress relief does not ensure adequate wear resistance and fatigue strength of sleeves and collars for sliding bearings. Such parts require surface treatment before grinding so that residual compressive stresses are produced to some depth in the subsurface layer which will compensate the tensile stresses subsequently produced by grinding. This method has been evaluated both theoretically and experimentally, the main problem having been to establish the depth of the compression layer  $\Delta H = d + C_{\Delta} v_w^a v_b^b s_1^q s_t^e$  ( $d$ - cutting depth,  $v_w$ - velocity of rotating wheel,  $v_b$ - velocity of rotating blank part,  $s_1$ - longitudinal feed,  $s_t$ - transverse feed,  $C_{\Delta}$ - empirical coefficient and exponents  $a, b, q, e$  all depending on physio-mechanical properties of blank material and grinding process parameters). The depth was measured by the four-probe method in a planned experiment. Blank bars of 35CrMo-YuA steel were ground in a model 3A151 machine with a PP24A25K6SM1 wheel to a 120 mm long thin rod 0.20 mm in diameter with a 0.32 surface finish between two 60 mm long heads 0.40 mm in diameter with a 1.25 surface finish, with chamfers at both ends and with round fillets at both shoulders. Grinding was done with  $v_w = 35$  m/s,  $v_b = 0.5$  m/s,  $s_1 = 0.5$  m/min,  $s_t = 0.01$  mm/(double pass), equivalent to  $\Delta H = 0.37$  mm, using I-20A industrial-grade oil as lubricant-coolant. After grinding, all specimens were tested for wear and fatigue. The results indicate that prehardening before grinding reduces by a factor of 1.5-1.7 the subsequent wear resistance with a corresponding slowdown of run-in and raises by a factor of 1.4-1.7 the subsequent fatigue strength under a flexural stress varying over the 15-35 MPa range at 25 cycles/s combined with a constant torsional stress of 15 MPa. Figures 2; references: 4 Russian. [195-2415]

## FORCES ACTING UPON BEARINGS OF SCREW COMPRESSORS

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 7, Jul 84 (manuscript received 21 Dec 83) pp 89-91

VINOGRADOV, A. N., candidate of technical sciences, docent, and  
KALOSHIN, A. V., engineer

[Abstract] A method is presented for determining the forces exerted by a compressed gas on the rotor bearings of screw compressors, as well as the

forces in the rotor gearing when no coupling gears are employed. It is found that the stresses acting upon the bearings can be viewed as the sum of a constant component and two periodic components: one related to the pressure of the compressed gas, and the other related to dynamic imbalance of the rotors. Calculation of the stresses on the bearings of a screw compressor makes it possible to construct a model of vibration activity and to determine the influence of the compressor operating conditions on the diagnostic signal. The method can also be used for design calculations of the parameters of unloading devices and for designing screw compressor rotor bearings. Figures 2; references: 4 Russian. [58-6900]

UDC: (531.787.2+536.5):621.387

#### SEMICONDUCTOR TEMPERATURE AND STRAIN GAUGES

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 9, Sep 84 pp 21-22

GORBACHUK, M. T., Engineer, MITIN, V. V., SHVARTS, Yu. M., Candidates of Physical-Mathematical Sciences, and TKHORIK, Yu. A., Doctor of Physical-Mathematical Sciences

[Abstract] A method is proposed which permits the same sensor to be used to measure the temperature and deforming stress (load), and which reduces the errors caused by the simultaneous influence of temperature and strain on the working element of the sensor. The findings are obtained on p-type germanium subjected to uniaxial loading, which disturbs the initial symmetry of the p-Ge. Formulas are derived which make it possible to determine the temperature and strain from the known resistance of the deformed specimen parallel and perpendicular to the axis of deformation. The method permits the strain sensing element to be made of lightly doped material; the temperature range is determined by the size of the interval in which the electrophysical properties of the material employed remain uniform. The results of experimentation using a gauge incorporating a sensing element made of a single crystal of p-type germanium with specific resistance of 42 Ohms per centimeter at room temperature. References 6: 5 Russian, 1 Western. [35-6900]

## MODERN ULTRASONIC FLOWMETERS

Moscow SOVREMENNYYE ULTRAZVUKOVYYE RASKHODOMERY in Russian 1984  
(signed to press 24 Aug 84)

GUREVICH, V. M. and TRUMAN, S. G.

[Abstract] This study reviews the current status of ultrasonic flowmeters on the basis of materials published in the Soviet Union and elsewhere. The following advantages of ultrasonic flowmeters over earlier instruments are cited: good measurement accuracy over wide range of flow rates; very high speed; capability of measuring pulsating flows; good reliability through elimination of moving parts; possibility in principle of measuring mass flow rate and serviceability when direction of flow changes; and the capability of measuring media ranging from liquid metals to cryogenic liquids and gases. Ultrasonic flowmeters are suitable for use as working as well as calibration facilities. A comparative analysis is made of the design methods employed in ultrasonic flowmeters: Doppler, ultrasonic oscillation drift schemes, eddy flowmeters with ultrasonic signal pickoff, correlation flowmeters, 'noise adaptors', open-stream flowmeters, devices employing mixed principles in which the ultrasonic oscillations play an auxiliary role, devices employing geometric combination of the speed of sound and the rate of flow, and equalized conversion methods. The basic operating parameters of the different methods are tabulated for easy comparison.

Ultrasonic flowmeters employing equalization conversion are used most widely. These devices convert the time- or phase-difference signal with and against the flow to a standard dc or fixed voltage signal. The characteristics of these instruments are examined using the example of frequency-time schemes. The block diagram and operation of a frequency-time flowmeter are analyzed in detail. The handling of systematic errors due to changes in the speed of sound in the flow between cycles, as well as additive error caused by instability of the tracking systems and multiplicative error due to instability of the internal multiplication coefficient is discussed. A scheme for providing an analog output without loss of speed is described. The control of echo signals caused by reverberation is analyzed. The methods used to excite the piezotransducers in ultrasonic flowmeters are outlined.

The trends in the development of ultrasonic flowmeters are analyzed, and the following directions are singled out: improvement of means for inputting the ultrasonic oscillations to the measurement section, developing methods and means for forming the flow in the measurement section, improving the accuracy of acoustic density meters and acoustic resistance measurement cells, improving secondary transducers, augmenting secondary transducers with means for expanding the functional capabilities of flowmeters under difficult industrial conditions, developing certification methods for ultrasonic flowmeters as standards, and developing multichannel devices.

The evolution of ultrasonic flowmetering is traced from the first generation; the heightened interest in equalization conversion in the 1960s is described.

Experience in the development of second-generation devices, as well as the rapid development of electronics, resulted in a scientific and engineering base for third-generation device development. Because of their superior metrological and operating characteristics, ultrasonic flowmeters will continue to be among the most important means for flow measurement. References 39: 17 Russian, 22 Western.  
[101-6900]

UDC: 531.787.913

#### PIEZORESONANT PRESSURE SENSORS

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 9, Sep 84 pp 19-21

MALEYKO, L. V., MALOV, V. V., RUDENKOV, A. P. and YAKOVLEV, I. V.,  
Candidates of Technical Sciences, and IBRAGIMOV, T. B., MAGLYSH, V. A.,  
MIGUKINA, O. F. and PITKEVICH, Engineers

[Abstract] Piezoresonant pressure sensors based on existing commercially produced high frequency  $\text{yxls} \begin{vmatrix} +35^{\circ}13' \\ +34^{\circ}30' \end{vmatrix}$  - cut thermostable piezo-elements are described. The possibility of developing a design series of piezoresonant pressure sensors operating in the 0.1-600 kPa range for measuring atmospheric pressure in enclosed spaces is examined. The use of a piezoresonator in a self-sustained oscillator circuit makes it possible to obtain a signal with frequency proportional to the amount of pressure applied. The maximum errors obtained meterological testing of a number of pressure sensor specimens at the Scientific Research Institute for Metrology imeni D. I. Mendeleev (Leningrad) are presented. It is found that the measurement range of piezoresonant sensors can be changed by changing the effective area of the membrane and the distance from the top of the piezoresonator to the edge of the electrode and from the bottom of the piezoresonator down to the edge of the electrode. The sensitivity of the sensor can be increased by making the ratio  $\lambda/B$  smaller. The use of a type-A piezoresonator is preferable for building high-precision position sensors. References 4: 3 Russian, 1 Western.  
[35-6900]

## SEALED REED RELAY LIMIT SWITCHES

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 9, Sep 84 pp 17-19

IVANOV, I. P. and SVINTSOV, G. P., Candidates of Technical Sciences, and YEFIMOVA, M. A., LEBEDEV, A. V., SAMSONOV, Yu. P., Engineers

[Abstract] Sealed reed relay limit switches are described which overcome the inherent deficiencies traditionally present in these devices: high material and labor consumption and difficult operation. Series VSG limit switches developed at the All-Union Scientific Research and Technological Planning Institute for Relay Engineering (Cheboksary) for use in machine building are described. The VSG1 has a single switching contact, the VSG2 a single normally open contact and the VSG3 a single normally closed contact. The VSG1 employs type MKS-27103 sealed reed relays, while the VSG2 and VSG3 employ KEM-1 reed relays. The magnet system, which consists of magnets and a plate, and the sealed reed relay are contained in a non-magnetic casing with a slit in it. The mathematical expression defining the geometric dimensions of the magnet system is given. The basic parameters of all three types of switches are tabulated. The VSG series switches can be used to replace VBK and BVK switches, thus saving electricity, labor and material, including silver. References: 2 Russian. [35-6900]

## CONTACTLESS POSITION SENSOR

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 9, Sep 84 pp 16-17

POPOV, I. I. and PYATLINA, G. S., Engineers, and Candidate of Technical Sciences Ye. A. SHULYAKOVSKIY

[Abstract] A new contactless position sensor for switching electrical control and signalling circuits based on the Hall effect is described. The control element (a permanent magnet) is fastened securely to the moving controlled member. When the controlled member reaches some assigned position, the magnetic field of the control element acts upon the sensing element (a Hall element), which outputs a signal whose voltage depends upon the direction of the vectors of the supply current and the magnetic induction. The output signal is fed to a switching element which converts the analog output signal to discrete measurement values. The actuating mechanism in order to stop, switch, reverse, etc., the controlled object. The schematic diagram, timing diagram and technical specifications of the sensor are presented. References: 3 Russian. [35-6900]

## IMPLEMENTATION OF INTERACTIVE MODE IN INDUSTRIAL PLANNING OPTIMIZATION CALCULATIONS

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 10, Oct 84 pp 4-6

SUKHININA, Yu. S, engineer, and KALNEY, L. Ye., engineer

[Abstract] Software on the basis of "Linear Programming in Automatic Control Systems" program decks and with KAMA remote data control has been developed for computer-aided optimization of industrial planning. Calculations for analysis of economic situations and optimization of the economic-mathematical model yield technical and economic parameters essential for a forecast covering a period of 10 years. The software includes correction tables for adjustment of input and intermediate data, dictionaries for display of output data, and information needed for strategizing the optimization process. The KAMA system operates in PL/1 and ASSEMBLER languages. The output data are fed to an alphanumeric printer for further processing on a YeS-7934 computer with a minimum 7000 kbyte GAM or BTAM memory in the MFT, MVT, SVS, SVM modes. The software is designed for implementation on a YeS-1040 computer capable of solving problems with 700 lines and 2500 columns of variable bits in a 1 Mbyte memory in 20 min, with 23% memory utilization, or on a YeS-1033 computer capable of solving problems with 170 lines and 200 variable bits in a 512 kbyte memory in 3-5 min. Figures 1; references: 2 Russian.  
[103-2415]

## SOFTWARE OF ECONOMIC-MATHEMATICAL MODEL FOR DEVISING TECHNICAL-INDUSTRIAL-FINANCIAL PLAN

Moscow PRIBORY I SISTEMY UPRAVLENIYA in Russian No 10, Oct 84 pp 6-8

MOROZOV, A. I., engineer, SHULYAKOV, Yu. N., engineer, AVRYATA, S. A., engineer, DOMOGATSKAYA, O. I., engineer, and MOSKAYEVA, N. B., engineer

[Abstract] Software with a deck of special-purpose programs has been developed by the Scientific-Industrial Association "Tsentrprogrammssystema" in Kalinin for a model-plan covering all technical and financial as well as production aspects of an industrial enterprise. This software is based on the system approach to operations planning and design. The model is essentially an acyclic graph for calculating five categories of performance indicators pertaining, respectively, to production volume and manufacturability, materials and tools, labor content and wages, capital investment for economic stimulation, production cost and profitability. Several variants are allowed for those indicators which can and should be calculated

in two or more different ways. The library of algorithms is organized for modular execution of programs and their subsequent functional synthesis, each performance indicator separately, made possible by sufficient functional redundancy in the model. This ensures maximum flexibility and minimizes any necessary debugging by confining corrections and replacements or additions to any particular module only. Data are processed in high-level programming language, with the aid of "Makrosistema" or "Krokus" computer techniques, using local data bases in the code-text form. The software is designed for execution of programs on YeS computers with 512-kbyte memories, the minimum requirement being a 64-kbyte memory with which a program deck for 500 product items will be processed in 1 1/2 hours. The software has been tested and issued at the Center of Financial Analysis and Planning and is now being tried under real conditions in industrial enterprises. Figures 2; references: 6 Russian.  
[103-2415]

UDC 621 752

# METHOD OF REDUCING VIBRATIONS IN MACHINES WITH HIGH-SPEED ROTOR ON BALL BEARINGS

Moscow IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 6, Jun 84 (manuscript received 17 Oct 83) pp 28-33

BALMONT, V. B., candidate of technical sciences

[Abstract] Vibrations in a machine with high-speed rotor mounted on geometrically imperfect ball bearings are analyzed, after three series of frequencies have been identified in the perturbation spectrum: 1) frequencies  $f_1 = \lambda n_r + k z n_s$  of vibrations caused by defects in the inner race; 2) frequencies of  $f_2 = \lambda n_r + 2 k n_b$  of vibrations caused by defects in balls and their interaction with race defects; 3) frequencies  $f_3 = n_r - n_s$  of vibrations caused by dimensional variance of balls ( $n_r$  - speed of rotor with inner race,  $n_s$  - speed of separator relative to inner race,  $n_b$  - speed of balls,  $z$  - number of balls,  $\lambda = 1, 2, \dots$ ,  $k = 0, 1, 2, \dots$ ). Narrowing the  $f_1$  spectrum, specifically, is possible when

$$n_s = \frac{m}{z} n_r \quad (m - \text{any natural number}) \text{ so that } \lambda + km \text{ are integers}$$

and this spectrum becomes  $f = (\lambda + km) n_r$ . From the standpoint of such a deterministic spectrum of vibration frequencies the design is then analyzed of ball bearings for reduction of vibration amplitudes. This is found to require that  $1/2 < m < 1/2\pi \cos \alpha$  ( $\alpha$  - bearing contact angle). These constraints have been applied to two pairs of radial bearings: standard 4-I2010 and high-precision 4-I2010T. Theoretical design calculations indicate and experimental data on two electric motors, each running with both types of bearings confirm that, with a definite ratio of ball diameter to diameter of the center circle, the perturbation frequencies can indeed be designed not to coincide with the natural frequencies and the amplitude of vibrations will thus be greatly reduced. Figures 1; tables 2; references: 3 Russian.  
[60-2415]

# CHARACTERISTICS OF MANIPULATOR FOR INDUSTRIAL ROBOT WITH THREE ROTATIONAL PAIRS HAVING PARALLEL AXES

Moscow IZVESTIYA VYSSHIKH UCHEBNIKH ZAVEDENIY: MASHINOSTROYENIYE in Russian No 6, Jun 84 (manuscript received 5 Jun 83) pp 54-57

POTEYEV, M. I., candidate of technical sciences

[Abstract] The dynamics of a manipulator with three rotational kinematic pairs having parallel axes are analyzed, for application in an industrial robot. The system of Lagrange equations of the second kind, describing the motion of such a mechanism in terms of kinetic energy in generalized coordinates, is reduced to equations of motion in terms of Newton's laws. These are useful not only for either determining the moments of force couples which will produce a prescribed motion or, conversely determining the motion which given force couples will produce but also for solving optimization problems under additional constraints in both cases and for solving optimization problems under additional constraints in both cases and for estimating dynamic errors. As a specific example is considered a manipulator with all three axes of rotation vertical. The performance of this manipulator, namely the parameters of its motion as functions of time, is compared with that of a manipulator having one rotational and two translational kinematic pairs. Computer-aided simulation of their motion on the basis of ideal models, with all three links represented by identical homogeneous bars, has yielded velocity-time diagrams which indicate that the manipulator with three rotational pairs is 4.5 times faster than the other one. Figures 3.

[60-2415]

UDC: 531.8

## CONTROLLING MOVEMENT OF MANIPULATOR WITH ALLOWANCE FOR ELASTIC OSCILLATIONS OF ARM

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84 (manuscript received 12 Jan 83) pp 38-46

BOLOTNIK, N. N. and GUKASYAN, A. A.

[Abstract] A mechanical model of a manipulator with three degrees of mobility is examined that consists of a stationary base, a pedestal, a vertically oriented shaft, a guide and an arm. The base, pedestal, shaft and guide are assumed to be absolutely solid bodies; the arm is a uniform elastic round rod subjected to slight flexing. The shaft of the manipulator moves vertically and rotates about the vertical axis; the arm moves back and forth along the guide. The system is controlled by virtue of the forces with respect to the axis of revolution of the shaft, the vertical force



applied to the shaft and the force applied to the arm. An expression is derived for the kinetic energy of the mechanical system. The problem of defining the control of the system of Lagrange equations describing the movement of the system is analyzed and found to have more than one solution. An algorithm is proposed for calculating the parameters of the control mode which provides the required positioning accuracy. The problem of controlling the rotation of the arm without extension or retraction is analyzed as an example. References 13: 10 Russian, 3 Western.  
[49-6900]

UDC: 531.8

#### CONTROLLING SPATIAL MOVEMENT OF BIPED WALKING APPARATUS

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 12 Apr 82) pp 47-53

NOVOZHILOV, I. V.

[Abstract] 'Rigid' direct control exploiting deviations from the programmed movement of a biped walking apparatus for flat longitudinal motion is a standard to the case of three-dimensional movement. The apparatus is configured to make the most natural use of previous findings for flat longitudinal movement. The possibilities of controlling the apparatus, which exhibits five degrees of freedom, are discussed. It is shown that the deviations between the phase coordinates and the program become asymptotically smaller for a programmed trajectory of the center of mass consisting of a straight line. The problem is similar to that of controlling the spatial movement of quadruped apparatus with the left and right legs contacting the ground alternately. References 10: 9 Russian, 1 Western.  
[49-6900]

UDC: 531.8

#### INFLUENCE OF SHOCK ON MOVEMENT AND POWER PROFILE OF BIPED WALKING APPARATUS

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 17 Feb 82) pp 54-62

RUTKOVSKIY, S. V.

[Abstract] This study extends previous work on the movement of a biped walking apparatus with controllable feet. The movement is constructed by the inverse method. The leg produces a shock as it strikes the walking surface; the controls are finite and continuous functions of time, so that the shock is passive and uncontrolled. Periodic movement is found when the shock occurs. The energy consumed by periodic movement is found by taking a

step, producing a shock and then making a second step with equalization. A numerical problem is analyzed as an example for the case in which the leg follows a parabola. References: 7 Russian.  
[49-6900]

UDC 681.325(088.8)

# CONVERTER OF ROTATING-TRANSFORMER SIGNALS TO CODE OF SUCCESSIVE-APPROXIMATION ANGLE

Moscow IZMERITELNAYA TEKHNIKA in Russian No 8, Aug 84 pp 18-20

DOMRACHEV, V. G. and PODOLYAN, V. A.

[Abstract] A cyclic converter of signals from a rotating sine-cosine resolver transformer to a binary code of the angle through successive approximations has been designed with large-scale to small-scale circuit integration. Its two channels yield informative outputs of 12-bit word length, the quantization level error not exceeding  $\pm 3'$  and the total cycle time not exceeding 220 S. There is a built-in 3570 Hz reference-frequency oscillator. The converter can operate with input signals of 2-12 V and draws 1.3 W from a  $\pm 15$  V power supply. The output code with TTL levels is a straight parallel or sequential one tracked by synchronization pulses. The conversion process is conventional, with mismatch signals being formed in accordance with the algorithm  $\sin\theta\cos\phi - \cos\theta\sin\phi = \sin(\theta - \phi)$  ( $\theta$ - angle of resolver transformer rotation,  $\phi$ - compensating angle equivalent to output code) and then reduced to zero digit-after-digit by the method of successive approximations. Variable input signals are converted into constant ones with the aid of a sampler-storage device. Other converter components are a read-only memory with synchronous pulse energizing and synchronous code recording, a digital-to-analog converter, four sign-inverting analog switches, a comparator with summation of products at the input and a trigger transmitting the comparator output signal to a successive approximations register, as well as analog switches for channel commutation and function commutation, operational amplifier, and resistor banks. Functions are recorded in the memory without deficiency, owing to addition of a modified memory which records codes with excess. The two memories do not have to operate simultaneously so that there is no net increase in the power drawn by the converter. Figures 2; references: 1 Russian.  
[79-2415]

## AMPLITUDINAL ANGLE-TO-CODE CONVERTER WITH ROTATING SINE-COSINE TRANSFORMER

Moscow IZMERITELNAYA TEKHNIKA in Russian No 8, Aug 84 pp 20-21

KUDRYASHOV, B. A., SMIRNOV, Yu. S. and SHISHKOV, A. B.

[Abstract] An angle-amplitude-code converter with rotating sine-cosine resolver-transformer has been developed which operates at high speed without large dynamic error, when only the digital equivalent of the angle is required without scaling or sine and cosine codes. The output signal of the rotating resolver-transformer passes through an angle-to-tangent and tangent-to-code converter which feeds the angle code to a read-only memory. That converter consists of a

code-to- $\frac{\sin}{\cos}$  converter, one octant detector, an

analog commutator, and an analog-to-digital converter. The rotating resolver-transformer is energized from a reference-voltage generator. The output signal of the octant detector is fed to the commutator and also to an exclusive-OR gate which receives the angle code from the memory and to a code storage register which receives the output signal from the exclusive-OR gate. That register forms and delivers the angle code. The instrument error is smaller here because code-to-voltage conversion has been eliminated, and there is no methodological error here so that the accuracy of this device is much higher than that of conventional angle-to-code converters. Figures 2; references: 2 Russian.

[79-2415]

## DISTRIBUTION OF LOSSES IN TWO-TURN COIL OF TWO-LAYER BAR WINDING IN POWER MOTOR

Moscow ELEKTROTEKHNIKA in Russian No 10, Oct 84 (manuscript received 4 Jan 84) pp 28-29

BOGUSLAVSKIY, I. Z., candidate of technical sciences, Leningrad Economic Planning Department of "Elektrosila" Association

[Abstract] Motors with speed regulation and good dynamic characteristics for driving machine tools require a low dynamic moment of inertia, which is attainable by minimizing the rotor diameter and increasing the length appropriately. The stators of such motors must have a bar rather than coil winding and a two-turn two-layer winding when designed for high-voltage operation. In order to design such a winding adequately for frequent short overloads without overheating, it is necessary to determine the distribution of losses in its turns and the corresponding rates of

temperature rise. This is done here according to Joule's law with the skin effect and time harmonics in the stator current taken into account. All m conductors stacked heightwise and n conductors stacked widthwise in each turn are assumed to be transposed so that the same current flows in each. Conductors are assumed to be rectangular and to lie in rectangular slots. Calculations on this basis reveal a highly nonuniform distribution of additional fundamental-frequency losses, in a ratio of 1:7:19:37 from the bottom turn of the lower layer to the top turn of the upper layer, and that the effect of time harmonics in the stator current is a less nonuniform distribution of additional losses. References 3: 2 Russian, 1 Hungarian.  
[109-2415]

UDC 621.313.32+621.313.33 .002.2"313"

IMPROVEMENT OF LARGE ELECTRICAL MACHINES PRODUCED AT 'URALELEKTROTYAZHMASH'  
PLANT IMENI V. I. LENIN

Moscow ELEKTROTEKHNIKA in Russian No 10, Oct 84  
(manuscript received 9 Jan 84) pp 31-34

KORENTSVIT, F. R., engineer

[Abstract] The production of large electrical machines at the "Uralelektrotyazhmash" plant has expanded tremendously in scope, from only altogether 40 units of 12 types produced in 1943 to over 120 types with a correspondingly larger volume produced in 1975. Various improvements in design and manufacture have been introduced since then. Induction motors, always predominantly of the vertical design with squirrel-cage rotors for pump drives, now include two-speed motors with pole-amplitude or phase-amplitude modulation, motors for thermal-reactor NPPs with forced-feed bearing lubrication and earthquake-proof features, and motors for fast-reactor NPPs with squirrel-cage rotors or with wound rotors and stator stacks of 0.5 mm thick electrical-grade steel laminations, production of vertical motors having been added to production of horizontal ones in the late 1960s. Synchronous compensators are now produced for outdoor duty at temperatures from -40°C to +40°C, brushless excitation having been developed in the late nineteen sixties jointly with the All-Union Scientific Research Institute of Electrical Machines and with hydrogen cooling being introduced now as latest feature. The largest machines now produced at the "Uralelektrotyazhmash" plant are 4000/2500 kW - 300/250 rpm two-speed induction motors, 4000-12,500 kW - 375-187 rpm synchronous motors, and 160 MVA synchronous compensators. Figures 1; tables 2.  
[109-2415]

## SELECTION OF TEST ACCELERATION FACTOR FOR BEARING ASSEMBLIES OF ELECTRICAL MACHINES

Moscow ELEKTROTEKHNIKA in Russian No 10, Oct 84 (manuscript received 4 Jan 84)  
pp 34-36

GOLDBERG, O. D., doctor of technical sciences, professor, GORBUNOV, A. G., candidate of technical sciences, and MURAVYEV, S. V., engineer, All-Union Scientific Research Institute of Electromechanics

[Abstract] The fundamental relation for the service life of ball bearings

$$L = \frac{10^6}{60N} \left( \frac{C}{P} \right)^3 \text{ hours (N, rpm - speed, P, kgf - equivalent dynamic load, C, kgf -$$

load capacity) serves as the basis for determining the mode of service life test acceleration. The test time can be shortened by the factor  $K_a = (P_o/P_n)^3$  ( $P_o$  - overload,  $P_n$  - nominal load), with a correction factor which accounts for the dependence of service life under a cyclic load on the mode of lubrication  $L_{lub}/L_{theor} = 1.24\lambda - 0.52$  ( $L_{lub}$  - service life with lubrication,  $L_{theor}$  - theoretical service life,  $= t/r$ ,  $t$  - thickness of lubricant film,  $r$  - reduced rms absolute roughness of surfaces in contact) and thus on the temperature rise. The test acceleration factor becomes then

$$K_a = \left( \frac{1.24\lambda_n - 0.52}{1.24\lambda_o - 0.52} \right) \left( \frac{P_o}{P} \right)^3. \text{ These relations were used for accelerating service}$$

life and failure tests of high-capacity high-precision ball bearings with three different plastic lubricants (aircraft grade TsIATIM-221, petrochemical grades VNIINP-242, 288) in wound induction motors, high-temperature Class H insulation of the motor coils ensuring that 90-95% of all failures under overload be bearing-related. Data on 308-310 bearings in TEN 55 kW motors running at 6000 rpm reveal, upon regression analysis, that degradation of the lubricant to zero electrical resistance at the critical temperature (160°C, 110°C, 120°C for lubricants 221, 242, 288, respectively) increases the vibration acceleration level from a steady mean initial 70 dB to 100-110 dB. Bearings should not be overloaded beyond  $0.9T_c$ ,  $T_c$  being the critical temperature for a given lubricant. Figures 2; tables 1; references: 7 Russian.

[109-2415]

HARDENING TREATMENT OF MACHINE PARTS WITH CO<sub>2</sub> POWER LASERS

Moscow ELEKTROTEKHNIKA in Russian No 10, Oct 84  
(manuscript received 1 Jun 83) pp 51-54

BORODACHEV, A. S., candidate of technical sciences, GUTMAN, M. B.,  
candidate of technical sciences, KUZNETSOV, G. A., engineer,  
MEDVEDOVSKAYA, L. A., candidate of technical sciences, and RUBIN, G. K.,  
doctor of technical sciences, All-Union Scientific Research Institute of  
Electrothermal Equipment

[Abstract] Two technological laser facilities have been built at the All-Union Scientific Research Institute of Electrothermal Equipment for hardening machine parts, one with the 1.2 CO<sub>2</sub>-laser developed at the Institute of Applied Mechanics (Siberian Department, USSR Academy of Sciences, Novosibirsk) and one with the 2.5 kW CO<sub>2</sub>-laser developed at the Institute of Problems in Mechanics (USSR Academy of Sciences, Moscow). Both lasers are continuous-wave devices with self-sustained gas discharge between flat anode and tubular cathode. The gas mixtures are CO<sub>2</sub>:N:He=1:3:2 and CO<sub>2</sub>:N:H<sub>4</sub>=1:1:8, respectively. The beam diameter is 80 mm and 96 mm, respectively. The corresponding power requirements is 40 kW and 60 kW, with oil cooling, 20-25 kW ensuring stability of the gas discharge with the mixture entering under a low pressure of 2 kPa at a high velocity of 35-40 m/s. Each facility includes a Fabry-Perot resonator, a beam transporting and focusing mechanism, a laser power measuring instrument with a movable beam-chopping mirror, and a helium-neon simulating laser with two mirrors for precision alignment of parts. These facilities are intended not only for hardening but also annealing, plating, and alloying. Under consideration is also their use for welding and cutting. Materials hardenable with these facilities range from perlite iron to chromium steels. Experimentally hardened parts include tool bits, gear teeth, zinc extrusion plungers, bearing races, king pins, bolts, and even diesel cylinders. Hardening is done so as to ensure high wear resistance of the material and long service life of the part. Figures 1; tables 1; references: 4 Russian.  
[109-2415]

## NEW METHOD OF SYNTHESIZING NOMINAL TRAJECTORY FOR MANIPULATOR ROBOTS WITH REDUNDANT DEGREES OF MOBILITY

Moscow MASHINOVEDENIYE in Russian No 4, Jul-Aug 84  
(manuscript received 28 Dec 82, after completion 6 Dec 83) pp 21-25

VUKOBRATOVIĆ, M. and KIRČANSKA, M., Belgrade/YUGOSLAVIA

[Abstract] The reverse problem of control for a manipulator with redundant degrees of mobility, namely synthesis of its nominal trajectory so as to eliminate the attendant indeterminacy, is solved by a new method which draws not only on the governing kinematic relations but also on the complete dynamic characteristics of such a mechanism. The dynamic characteristics can be evaluated by any method, from general theorems of mechanics as well as from corresponding Lagrange or Gibbs-Appel equations. Here the problem is formulated in generalized Lagrange coordinates for a manipulator with  $n$  degrees of mobility. Solution of the problem includes optimization of the vector of their first derivatives, i.e., of velocities at successive instants of time for minimum energy losses in the manipulator drives. The procedure and a numerical solution are demonstrated on synthesis of a continuous trajectory for a manipulator with four degrees of mobility. The results indicate that integration must be performed over time intervals sufficiently short to minimize the optimization error and sufficiently long to avoid numerical instability of matrix inversions, in this particular case  $10 \text{ ms} \ll \Delta t \ll 50 \text{ ms}$ . Figures 2; references 10: 1 Russian, 10 Western. [54-2415]

## INDUCED VIBRATIONS AND RESONANCE OF SHAFT UNDER NONSTEADY LOAD

Kiev PRIKLADNAYA MEKhanika in Russian Vol 20, No 9, Sep 84  
(manuscript received 8 Jun 82) pp 103-110

VESNITSKIY, A. I., MILOSERDOVA, I. V. and POTAPOV, A. I., Gorkiy State University

[Abstract] Torsional vibrations of the rotating shaft in a slider-crank mechanism are analyzed, first induced vibrations outside the ranges of parametric instability. The corresponding equation of motion is solved for appropriate boundary conditions at both drive end and load end of the shaft, after the boundary conditions have been linearized and reduced ones with a periodically varying parameter in coordinates of forward and backward traveling waves. An analysis of the solution reveals anharmonic natural vibrations and resonance under a load with a frequency equal to the time derivative of their phase. The simplest special case is uniform shaft

rotation. For an analysis of the mechanism within a range of parametric instability, with stringent constraints on the rate of change of the moment of inertia, the sought solution must be resolved into combination modes. Such a solution can be found exactly. It describes steady-state interaction of induced and parameteric vibrations, parametric amplification and attenuation of induced vibrations, and excitation of pulsations. Figures 5; references 13: 11 Russian, 2 Western.  
[52-2415]

UDC 621-822.5

#### ENGINEERING DESIGN AND OPTIMIZATION OF RADIAL AEROSTATIC BEARINGS

Moscow MASHINOVEDENIYE in Russian No 4, Jul-Aug 84 (manuscript received 11 Jan 83) pp 84-91

BALASANYAN, V. S. and ZHAPPAROV, N. Sh., Moscow

[Abstract] The engineering method developed earlier by V. S. Balasanyan for design and optimization of horizontal radial aerostatic guide bearings with discrete feed and supercharge is now refined by including the dimensions of pockets and the throttling of air twice, first through an orifice and then through an annular diaphragm in the clearance upon exit from a pocket. This is in addition to including the effect of circumferential leakage on the corrections to two discreteness factors in calculation of bearing stiffness and pressure-flow distribution, as well as on the "supercharge lines" schematic. The bearing performance parameters are evaluated on this basis, first analytically and then numerically. The results reveal that inclusion of the double throttle improves the accuracy of calculations appreciably when the areas of orifice and diaphragm are comparable. The size of the pocket diameter affects the optimum orifice diameter and the bearing stiffness, both increasing somewhat as that diameter is increased. In the real case of a large pocket, throttling occurs principally through the orifice, however, and comparison with experimental data reveals that accounting for the double throttle does not significantly improve the accuracy of performance calculations. Figures 3; tables 2; references 11: 10 Russian, 1 Western.  
[54-2415]



## DYNAMIC DESIGN OF SLIDING BEARINGS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 8, Aug 84 pp 9-12

KHOMENKO, I. M., candidate of technical sciences

[Abstract] The design and performance of a sliding bearing under dynamic conditions are analyzed, the object being to determine the maximum allowable shaft (rotor) unbalance and the minimum thickness of lubricant film for a given minimum radial clearance. The calculations are based on the theory of motion of unbalanced bodies, unbalance being defined as the distance from geometric center to center of mass and the shaft assumed to be in equilibrium when the centers of both bearings lie on a horizontal line. Conditions of shaft oscillation with unilateral bearing wear and of shaft precession with unilateral shaft wear are considered, depending on whether the inertia load is respectively smaller or larger than the static load (rotor mass), but the worst case being the critical condition where both are equal so that breakaway and impacts can occur. Figures 4; references 3: 2 Russian, 1 Western.(?)  
[74-2415]

## MATCHING HEAD AND CAVITATION CHARACTERISTICS OF TWIN AXIAL (WORM-TYPE) PUMP IMPELLERS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 8, Aug 84 pp 12-14

SHCHERBATENKO, I. V., candidate of technical sciences, and SHAPIRO, A. S., doctor of technical sciences

[Abstract] The cavitation characteristics of centrifugal pumps are improved by placing a worm impeller in front of the main one, which also raises the second critical "breakaway" cavitation factor from 1500-2500 to 4000-5000. A further improvement of such centrifugal-worm pumps is the addition of another worm impeller in front of the other one, either on a separate shaft rotating at a lower speed or on the same shaft with a larger radial clearance. The problem is to match the cavitation factor, now in the 15,000-20,000 range, with the specific speed and thus with the head. The vanes of this auxiliary impeller are set at an angle which will ensure cavitation breakaway simultaneously at both worms so as to maximize the working head in both worm impellers with the critical margin of cavitation head at its minimum. The maximum blade angle which cavitation in the auxiliary worm impeller will permit is determined theoretically from the parameters of the "presupercavitation" state, which differs from the second critical "breakaway" state in the downstream flow only. The analysis can thus be reduced to

conventional theory. Calculations on this basis are made for a twin-worm impeller with uniform vane pitch in a viscous incompressible fluid. The dependence of the blade setting angle on the pump capacity and the fringe losses is obtained for design purposes. The dependence of the hydraulic efficiency on the blade setting angle for a given pump capacity is obtained for performance evaluation. Figures 3; references 8: 6 Russian, 2 Wester. [74-2415]

UDC 621.822.6:621.5.001.24

INTEGRAL METHOD OF CALCULATING LOADS ON BEARINGS IN GEAR-TYPE ROTARY PUMPS WITH LIMITED WORKING SPACE

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 8, Aug 84 pp 15-17

RUDOY, E. I., engineer, and GARKUSHA, A. G., engineer

[Abstract] The performance of gear-type rotary pumps, which operate under periodically varying flow rate and outlet pressure, depends largely on the loads on the gears and their bearings. These loads are determined by the correspondingly varying dimensions of the high-pressure zone and are calculated either exactly at only several critical points, a laborious procedure, or on the basis of only approximate empirical relations. Integral averaging of the variable quantities is proposed instead, so as to combine simplicity with infinitesimal discretization. The total load on a bearing is the sum of the hydraulic pressure by the fluid and the tooth contact pressure transmitted through the seals. The instantaneous horizontal and vertical components of hydraulic pressure are integrated with respect to the coordinate of the tooth contact point on the line of action over a full tooth pitch on the base circle, assuming a constant speed of rotation and thus a uniform motion of the contact point. For numerical data and illustration of the method, calculations have been made for NSh50-3 and NSh250-3 pumps developing a pressure head of 16 MPa. Figures 2; references: 2 Russian. [74-2415]

## EFFECT OF UNDERCOATING BY HEAT AND AIR BLAST TREATMENT ON TRIBOLOGICAL CHARACTERISTICS OF SOLID LUBRICANT IN STEEL FRICTION PAIRS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 8, Aug 84 pp 26-27

RUBTSOVA, Z. S., candidate of technical sciences, Sentyurikhina, L. N., doctor of technical sciences, Protasov, G. A., candidate of technical sciences, and Lopukhin, V. I., engineer

[Abstract] The effectiveness of solid lubricants such as molybdenum disulfide coated on the mating surfaces of friction pairs can be further increased, in terms of wear reduction, by undercoating the surfaces with a layer of nickel-chromium steel or a high-chromium steel + molybdenum composite. An experimental study of this technique was made on friction elements made of 1Kh18N9T stainless steel. The material for undercoating was melted in the electric arc of an EM-14 machine and then blasted from the interelectrode space onto the target surfaces with a stream of compressed air, all this was done at the All-Union Scientific Research Institute of Gas Welding and Metal Cutting. Solid lubricant coating was deposited after grinding and sand (corundum) blasting of the undercoated surface. Tests at temperatures of 20-150°C with rubbing velocities of 0.23-0.87 m/s under an initially 1290-1760 MPa contact pressure were performed on friction pairs with 100-110  $\mu\text{m}$  thick undercoatings and, for comparison, without undercoatings. These tests were performed in a DSh machine, with the principal friction pair consisting of a rotating 1Kh18N9T steel disk and a stationary EI347 steel ball. The results indicate that the maximum wear resistance of the mating surfaces is attained by undercoating either both surfaces or the one which will not be subsequently coated with solid lubricant, in the latter case the solid lubricant being preferably deposited on the surface with the larger working area. Tables 1; references: 4 Russian. [74-2415]

## 'INDA' HIGH-TEMPERATURE LUBRICANT FOR CONVEYOR-BELT BEARINGS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 8, Aug 84 pp 27-28

Kobzova, R. I., candidate of chemical sciences, Bakaleynikov, M. B., candidate of technical sciences, Yegorova, Z. D., engineer, and Strokova, Ye. F., engineer

[Abstract] A new high-temperature bearing lubricant has been developed for conveyor belts passing through treatment chambers with temperatures of 250-300°C. This "Inda" material contains neither fast-depleting synthetic or mineral oil nor high-cost scarce polyorganosiloxanes, only polymer

materials capable of forming solid films without special deposition techniques. The material has a molecular mass of 5000 and its characteristics are kinematic viscosity ranging from 1270  $\mu\text{m}^2/\text{s}$  at 20°C to 67  $\mu\text{m}^2/\text{s}$  at 100°C, congealing point -40°C, flash point 240°C in open crucible, pH = 6.5-7.7, acid number 0.1 mg KOH/g oil, and tensile strength 80 Pa. The material was tested in an automobile manufacturing plant and there found to ensure an average bearing life of 2-3 years, including 5000 h at 260-300°C, without replenishment of lubricant. Tables 2.  
[74-2415]

UDC 621.891

#### EFFECT OF CuI IN POLYMER LUBRICANT ON FRICTION CHARACTERISTICS

Moscow VESTNIK MASHINOSTROYENIYA in Russian No 8, Aug 84 pp 28-29

GRIBAYLO, A. P., candidate of technical sciences

[Abs tract] The effect of adding 10% CuI to polymer lubricants, specifically to the "Central Scientific Research Institute of Aircraft Fuel and Lubricants" grade 201 material, was tested on \*St45 steel - SCh15 gray iron\* and \*SCh21 gray iron - SCh21 gray iron\* pairs in a friction machine with a stationary disk and a rotating wheel at a rubbing velocity of 0.17 m/s and under a constant load of 2.56 MPa at 296-298°C. The base material TsIATIM-201 was also tested alone and with each of five other additives (10% CuO, 10% CuO<sub>2</sub>, 10% Cu, 10% MoS<sub>2</sub>, 10% graphite). The results indicate that CuI has the largest positive effect, in terms of reducing the friction coefficient and the wear rate. The large magnitude of this favorable effect is attributable to a copper film forming on a friction surface as a result of chemical reaction. Figures 2; tables 2; references: 1 Russian.  
[74-2415]

/9835

DETERMINATION OF THERMAL ECONOMY OF TURBINE FACILITIES IN NUCLEAR ELECTRIC PLANTS

Kiev ENERGETIKA I ELEKTRIFIKATSIYA in Russian No 2, Apr-Jun 84 pp 1-3

[Article by V. F. Steshenko, engineer, Rovno AES]

[Text] Advanced development of AES in the European part of the USSR will in the near future involve a large number of specialists for operational service.

A problem that is becoming urgent for AES is keeping down expenses in meeting the requirements of the "Rules for Technical Service of Electric Plants and Networks" [1]. However, the literature does not adequately cover the problems of specific production economics of AES with their distinguishing features.

The procedure proposed by the author for thermal express testing of AES equipment with VVER reactors is an attempt to provide the necessary assistance in solving problems of improving economy of nuclear power, and at the same time to address a number of important engineering problems in AES: circumventing difficulties in measuring flowrate and moisture content of steam for wet-steam turbines of AES; improving safety in carrying out experiments; cutting down the time for doing experiments, and reducing the number of personnel involved.

In analyzing the economy of AES equipment, the main technical characteristic is the specific consumption of heat by the turbine unit, which is traditionally determined by an enormous number of measurements of the amount of heat delivered to the turbine unit. This method of determination is known as the "method of direct balance."

The procedure proposed here is based on measuring the amount of heat taken from the circuit of the turbine unit, and can rightly be called the "method of return balance."

The energy balance of the turbine unit can be represented for the case with electric feed pump in the following form:

$$Q_{t.u}^{gr} + Q_{rec} = 0.86N_g + \Sigma Q, \quad (1)$$

where  $Q_{t.u}^{gr}$  is the amount of heat delivered to the turbine unit from the steam generators, Gcal/hr;  $Q_{rec}$  is the recuperated part of the pumps for regenerative heating of the feed water, Gcal/hr;  $N_g$  is the power across the generator leads in MW.

$$Q_{\text{rec}} = 0.86(\Sigma N_{\text{r.p}} - \Sigma \Delta N_{\text{r.p}} + N_{\text{f.p}} - \Delta N_{\text{f.p}}), \quad (2)$$

where  $\Sigma N_{\text{r.p}}$  is the electric power of the regeneration pumps, MW;  $\Sigma \Delta N_{\text{r.p}}$  is the unrecuperated power of the regeneration pumps, MW;  $N_{\text{f.p}}$  is the electric power of the feed pumps, MW;  $\Delta N_{\text{f.p}}$  is the unrecuperated power of the feed pumps, MW.

The quantity of heat taken off from the circuit of the turbine unit can be represented as follows:

$$\Sigma Q = Q_1 + Q_2 + Q_3 + Q_4 + Q_5, \quad (3)$$

where  $Q_1, Q_2, Q_3, Q_4, Q_5$  is the quantity of heat in Gcal/hr taken off from the condenser with cooling water, from the turbine bearings, from the generator bearings, from the insulation surface, and with leakages of working heat from the circuit of the turbine unit respectively.

The first member of equation (1) defines the amount of heat expended on producing electric energy, and coincides with a similar relation generally accepted for electric power plants. The second member of equation (1) determines the balance of heat flows.

Dividing equation (1) by  $N_g$  term by term, we get expressions for determining the gross specific heat consumption (Gcal/MW) by the turbine facility with respect to "direct balance"

$$q_{\text{t.u}}^{\text{gr}}(\text{dir}) = \frac{Q_{\text{t.u}}^{\text{gr}} + Q_{\text{rec}}}{N_g}, \quad (4)$$

and with respect to "return balance"

$$q_{\text{t.u}}^{\text{gr}}(\text{ret}) = 0.86 + \frac{\Sigma Q}{N_g}. \quad (5)$$

An estimate of thermal losses  $Q_2$ - $Q_5$  can be made by a graphoanalytic method.

The amount of heat carried away from the turbine bearings is determined from the expression of heat balance, Gcal/hr,

$$Q_2 = 0.86 \frac{\alpha N_t (1 - \eta_m)}{\eta_m}, \quad (6)$$

where  $\alpha \approx 0.9$  is a coefficient taking account of the fact that not all heat losses are carried off to the coolant, but some are dissipated to the ambient [2];  $\eta_m = 0.97$ - $0.99$  is mechanical efficiency [3].

The quantity of heat carried off from the generator is determined by analogy (Gcal/hr)

$$Q_3 = 0.86 \frac{\alpha N_g (1 - \eta_g)}{\eta_g}, \quad (7)$$

where  $\eta_g = 0.98$ - $0.99$  is generator efficiency [3].

The amount of heat carried off from the insulation surface and with leakages of working heat we determined from the expression (Gcal/hr)

$$Q_4 + Q_5 = 0.86 \frac{N_t(1 - \eta_{1k})}{\eta_{1k}}, \quad (8)$$

where  $\eta_{1k} = 0.975$  is a coefficient that accounts for heat losses from the insulation surface and with leakages [3].

On the basis of expressions (1-8) we can readily compute heat losses by the turbine unit under different loads and plot a graph. In application to the K-220-44 turbine of Kharkov Turbine Plant (Fig. 1 and Table 1).

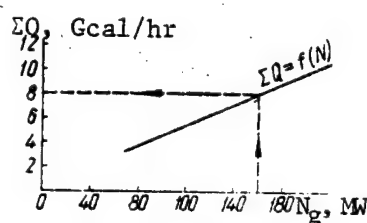


Fig. 1. Load dependence of sum of thermal losses of K-220-44 turbine unit

TABLE 1

Notation	Load, MW		
	$0.5N_g^{nom}$	$0.8N_g^{nom}$	$N_g^{nom}$
Thermal losses, Gcal/hr			
$Q_2$	1.7	2.8	3.5
$Q_3$	1.3	2.1	2.6
$Q_4 + Q_5$	2.4	3.8	4.9
$\Sigma(Q_2 + Q_3 + Q_4 + Q_5)$	5.4	8.7	11.0

The heat loss  $Q_1$  with the cooling water of the condensers is the major part of the balance of losses.

The main criteria of operation of a condensation unit that characterize the state of the turbine facility under prescribed conditions (steam load of the condenser, flowrate and temperature of cooling water) are: pressure of depleted steam in the condenser  $P_c$ , and the temperature head  $\delta t$  (difference between the temperature of steam and cooling water at the condenser outlet) that corresponds to the prescribed conditions.

The steam load of the condenser (flowrate of steam into the condenser) in operational monitoring is generally determined from the steam pressure in the chamber of one of the regenerative takeoffs to the low-pressure heaters, which

is the control level. For the K-220-44 turbine according to plant specifications we can take the steam pressure in the chamber of the fifth takeoff in the nominal mode at nominal live steam parameters

$$P_c = p_5^{\text{nom}} = 3.03 \text{ abs. at;} \\ D_c^{\text{nom}} = 787 \text{ t/hr,}$$

where  $D_c^{\text{nom}}$  is the flowrate of condensate after the condensers with consideration of the additional water flows out of the system.

The steam flowrate in the condenser is [4]

$$D_c = k P_c, \quad (9)$$

where  $k$  is the flowrate factor for the given K-220-44 turbine:

$$k = \frac{D_c^{\text{nom}}}{P_c} = \frac{787}{3.03} \approx 260.$$

In accordance with expression (9) we compile Table 2 and plot a graph (Fig. 2) of the steam flowrate in the condenser of the turbine unit versus the pressure in the chamber of the steam takeoff.

TABLE 2

Parameters	Calculated values					
$P_c$ , abs. at	0.5	1.0	1.5	2.0	2.5	3.03
$D_c$ , t/hr	130.0	260.0	390.0	520.0	650.0	787.0

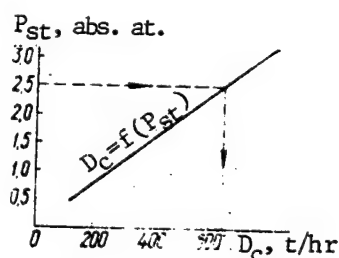


Fig. 2. Steam pressure in takeoff chamber as a function of steam flowrate in condenser of K-220-44 turbine unit

The amount of heat  $Q_1$  taken off from the condenser, and the flowrate of cooling water under service conditions are generally not measured, but are determined from the heat balance of the condenser

$$Q_1 = D_c(i_c - \bar{c}t_c) = G_w(t_2^w - t_1^w),$$

where  $t_1^w$ ,  $t_2^w$  are the temperatures of the cooling water at the condenser inlet and outlet respectively, in  $^{\circ}\text{C}$ ;  $G_w$  is the flowrate of cooling water to the



condenser, t/hr;  $\bar{c}t_c$  is the enthalpy of the condensate, Gcal/t;  $i_c$  is the enthalpy of steam at the condenser inlet, Gcal/t.

Since determination of the enthalpy of spent wet steam involves certain difficulties, for practical purposes the factor  $(i_c - \bar{c}t_c)$  can with sufficient accuracy be taken as constant and equal to 0.525 Gcal/t.

For the K-220-44 turbine unit under nominal load at nominal live steam parameters

$$Q_1 = 787 \times 0.525 = 414 \text{ Gcal/hr.}$$

A distinguishing feature of the proposed express method is that the temperature of the cooling water at the condenser inlet and outlet is continuously measured under service conditions, and these measurements can be used for rapid on-line determination of thermal economy of the turbine facility on a systematic basis.

Given below is summary Table 3 of thermal losses according to the "return balance" method for the K-220-44 turbine unit.

TABLE 3

Notation	Thermal losses	
	Gcal/hr	%
$Q_1$	414.0	97.4
$Q_2 + Q_3 + Q_4 + Q_5$	11.0	2.6
$\Sigma Q$	425.0	100.0

The specific gross heat consumption by the K-220-44 turbine unit according to "return balance" is

$$q_{t.u}^{gr}(\text{ret}) = 0.86 + \frac{425}{220} = 2.79 \text{ Gcal/MW.}$$

The specific gross heat consumption by the K-220-44 turbine unit calculated by "direct balance" under the same conditions but with more involved studies is 2.78 Gcal/MW.

The error of the "return balance" method is no more than 0.5%.

#### CONCLUSIONS

The proposed "return balance" method allows us to:

1. Determine the instantaneous value of operational economy of a turbine unit by a simple procedure of taking measurements of the cooling water temperature, and using the proposed formulas and graphs.

2. Analyze the influence of different factors on turbine unit economy.
3. Circumvent difficulties of measuring flowrate and moisture content of steam for wet-steam turbines in AES.
4. Improve safety in doing experiments at AES.
5. Cut down appreciably on the numbers of personnel involved in experiments.

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CSO: 1861/308

EFFICIENCY OF ADJUSTABLE NOZZLE STAGE FOR POWER TURBINE IN PLAIN-CYCLE  
DOUBLE-SHAFT GAS TURBINE ENGINE OPERATING AS STATION DRIVE

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian No 8,  
Aug 84 (manuscript received 5 Jan 83) pp 95-98

REVZIN, B. S., candidate of technical sciences, docent, FEDORCHENKO, M. Yu.,  
engineer, and NOVIKOV, S. V., engineer, "Order of Labor's Red Banner"  
Ural Polytechnic Institute imeni S. M. Kirov

[Abstract] A characteristic undesirable feature of the gas engine turbines now used as station drives is the decrease of delivered power during the warm season and following a drop in turbine and compressor efficiencies. An adjustable nozzle is the most efficient second means of performance control, with accompanying maintenance of the hottest gas temperature constant at either the turbine entrance or turbine exit. This problem is particularly serious when a single-compressor double-shaft aircraft engine is to be converted for pumping natural gas through a pipeline. As an alternative to using an oversize engine and thus providing the necessary extra margin of available power, an adjustable nozzle stage has been developed for the power turbine of specifically a 16 MW gas turbine engine. In order to minimize the number of possible variants and thus simplify the input data, a plain-cycle double-shaft engine was considered, with the ambient air temperature 15°C, the turbine inlet temperature 900-920°C, the compression ratio within the cycle 11:1 to 12:1, the turbine efficiency 88% and the compressor efficiency 85%. The thermal capacities were averaged over the compression process and the expansion processes, respectively. Addition of the nozzle stage was assumed to reduce the turbine efficiency by 2%. A comparative evaluation of engine performance with and without such a nozzle at three specific speeds (1.0, 1.1, 1.2 nominal) reveals the main advantage of an adjustable nozzle stage, namely a more economical increase of available power in summer than by use of oversize engine and especially so with precooling of the ambient air. Additional advantages are the possibility of starting far below the compressor's stability limit, better dynamic characteristics of the engine, the possibility of compensating for manufacturing imprecision and variance, and the possibility of adapting a factory-built engine to field conditions. Article was presented by Department of Turbine Construction. Figures 3; tables 1; references: 2 Russian.  
[56-2415]

INCREASING ENERGY EFFICIENCY OF CAPSULAR REVERSIBLE TURBINE-GENERATOR SETS.  
IN TIDAL ELECTRIC POWER PLANTS BY MEANS OF SPEED REGULATION

Moscow GIDROTEKHNICHESKOYE STROITELSTVO in Russian No 2, Feb 85 pp 13-17

DMITRIYEV, S. G., engineer, and PIKOVSKIY, A. V., engineer

[Abstract] Speed regulation has been proposed for improving the performance of capsular turbine-generator sets in tidal electric power plants, operating at low pressure heads under conditions of wide head and load variation. This method, already successful in pumped-storage hydroelectric power plants and adaptable to capsular sets, requires that the set be capable of variable-speed forward and reverse operation, not only as turbine-generator but also as motor-pump. While conventional adjustment of guide vanes and impeller blades in the turbine-pump part is adequate, a special electric machine is required for the generator-motor part. A synchronous induction machine readily allows smooth two-stage speed regulation, but requires a more intricate design of the rotating armature with polyphase windings and a more intricate excitation scheme as well as a starter for motor acceleration to near synchronous speed. Such a machine was installed and tested in the Kislogub PES, a Neupique Cie. (France) 400 kW - 72 rpm reversible turbine-generator set with a Krupp GmbH (FRG) planetary gear transmission. The set was run with a thyristor bank for pulse-phase frequency conversion and a fast-acting speed regulator, according to a program devised by the All-Union Scientific Research Institute of Electrical Engineering and at the Scientific Research Station of the All-Union Planning-Surveying and Scientific Research Institute imeni S. Ya. Zhuk with assistance from the "Elektrosila" Scientific-Industrial Association. Universal head-power characteristics were measured over the respective ranges of 0.6-2.5 m and 10-400 kW, at constant synchronous speed and at variable speed. The results indicate that speed regulation over the  $\pm 30\%$  range raises the efficiency of a forward-running turbine by 4.5% and of a reverse-running turbine by 11.2%, with double and single regulation, respectively, while it also raises the output power at partial pressure heads. Figures 5; tables 1; references 4: 3 Russian, 1 Western.

[203-2415]

## OPERATING CHARACTERISTICS OF WATER TURBINES IN NUREK GES AND SAYANSK GES

Minsk IZVESTIYA VYSSHIKH UCHEBNYKH ZAVEDENIY: ENERGETIKA in Russian No 8, Aug 84 (manuscript received 5 Jul 83) pp 114-117

CHISTYAKOV, A. M., candidate of technical sciences [deceased], All-Union Scientific Research Institute of Hydraulic Engineering imeni B. Ye. Vedeneyev, SAMORUKOV, I. S., candidate of technical sciences, "Order of Lenin" Leningrad Polytechnic Institute imeni M. I. Kalinin, and IVANCHENKO, I. P., candidate of technical sciences, Scientific-Industrial Association imeni I. I. Polzunov

[Abstract] The performance characteristics of 310 MW water turbines operating in the Nurek GES and the Sayansk GES were analyzed and evaluated numerically from the efficiency standpoint, with the reduction of losses in the penstock being especially important for high-head turbines in general and these turbines under a nominal 223 m head in particular. The calculations were made for given values of the total head covering the entire range in 5 m steps. For each value of the total head, the turbine input power was calculated from the turbine output power, with the generator load varied in 20 MW steps and the generator efficiency assumed to remain 97%. For each load level were calculated the approximate turbine efficiency with the turbine head assumed to be equal to the total head, the rate of water flow through the turbine, and the loss of head in the penstock, then the exact turbine efficiency at given turbine input power levels, and the penstock efficiency with the generator load varied but the total head assumed to remain constant. The calculations were based on factory data referring to a generator operating at a  $\cos \phi = 0.9$  power factor and on the Darcy-Weisbach relation  $\Delta h = k(L/D)(v^2/2g)$  for the penstock in the case of unavailable experimental data. Article was presented by Department of Water Power Utilization. Figures 3; references: 3 Russian. [56-2415]

## EXPERIENCE WITH FIRST 1200 MW - 3000 RPM TURBOGENERATOR IN SERVICE

Moscow ELEKTROTEKHNIKA in Russian No 10, Oct 84 (manuscript received 19 Oct 83) pp 11-12

KHUTORETSKIY, G. M., doctor of technical sciences, and DANILEVICH, Ya. B., doctor of technical sciences

[Abstract] The largest 2-pole electric turbogenerator in the world, the TVV-1200-2, built by the Leningrad Economic Planning Department of "Elektrosila" Association, is now operating in the Kostroma GRES under

nominal load. This is a 2-pole 6-phase 24 kV machine, rated for 1200 MW -  $\cos\phi = 0.9$  - 1333 MVA at 3000 rpm, with a short-circuit ratio of 0.45 and with hydrogen-water cooling (hydrogen pressure 0.5 MPa). Its unit weight is 0.47 kg/kVA. The machine was tested in service under partial loads of 305.5-1186 MW, under full load, and under a maximum overload of 1215 MW. Its outstanding features are the only-moderate heating of all windings and the stator core, with the temperature rise of the field coils not exceeding 41.7°C and that of the hottest stator end stack not exceeding 72°C under full load, and the stable low level of vibrations under heavy electromagnetic loading. The rotating subexciter with permanent magnets had to be replaced with a static one energized from the generator busbars so as to improve its connection to the main exciter and thus avoid low-frequency torsional shaft vibrations. The high noise intensity of brushless exciters required installation of a sound-proofing shield around them. Excessive heating of the lubricating oil, caused by turbulence of its flow through the clearance between shaft neck and seal ring, and to be precluded by installation of deturbulizing barriers in that clearance. Experience with startup and alignment of large turbogenerator sets on long shafts indicates a need for thorough balancing of each rotating member with respect to vibration modes of the aggregate and for continuous monitoring of those vibrations. Commercial production of TVV-1200-2 turbogenerators is recommended, for installation in thermal electric and nuclear power plants. Tables 3; references: 2 Russian. [109-2415]

UDC 621.313.322-81.026.449.018.782.3

# ELECTROMAGNETIC PARAMETERS AND CERTAIN TRANSIENT PROCESSES IN 500 MW TURBOGENERATORS

Moscow ELEKTROTEKHNIKA in Russian No 10, Oct 84  
(manuscript received 20 Feb 84) pp 14-18

ZABOLOTNYY, I. P., candidate of technical sciences, KAPLUNOV, V. B., candidate of technical sciences, LARIN, A. M., candidate of technical sciences, LERNER, L. G., candidate of technical sciences, and ROGOZIN, G. G., candidate of technical sciences

[Abstract] Accurate prediction of transient processes is necessary for ensuring reliable operation of electrical machines under unavoidable abnormal conditions. This problem is solved here for 500 MW turbogenerators on the basis of an adequate mathematical model describing the electromagnetic state of a synchronous machine, using available design and performance data. Two generators are considered, the TGV-500-2 two-pole machine and the TGV-500-4 four-pole machine, both designed for a nominal voltage of 20 kV and a full-load current of 17.0 kA at a 0.85 power factor. Their electric loading and magnetic induction in the air gap differ, the former being 1965 and 1840 A/cm, respectively, and the latter being 0.86 and 0.95 T, respectively. Analysis of starting or any other variable-speed transient,

during which the machine is an asynchronous one, is based on its current-slip and power-slip characteristics, usually obtained with the field winding shorted. Calculations by the method of successive approximations take into account saturation. This is done in two ways: 1) the equivalent rotor resistance is calculated iteratively as  $r_i(s) = r_{i-1}(s) \sqrt{\mu_i / \mu_{i-1}}$  ( $s$ - slip,  $\mu = f_1(H) = x_1(s) / r_1(s) = 0.6 + 0.71e^{-H_i/14.5}$  is used ( $H_i$ - magnetic field intensity,  $x_1$ - rotor reactance)). Calculations for the two-pole machine confirm experimental data based on field decay. Calculations for the four-pole machine indicate that it can hold the load longer during loss of excitation. A load-shedding rate of 27 MW/s is sufficient for maintenance of stability of 8 s, while the two-pole machine requires an unloading rate of 37.5 MW/s. Figures 5; tables 4; references 9: 6 Russian, 3 Western (1 in Russian translation).  
[109-2415]

UDC 621.313.322-81.001.4

# FACTORY TESTING OF POWER TURBOGENERATORS WITH BIFILAR CONNECTION OF ROTOR COILS

Moscow ELEKTROTEKHNIKA in Russian No 10, Oct 84  
(manuscript received 24 Jul 83) pp 18-20

KHUTORETSKIY, G. M., doctor of technical sciences, DROZDOVA, L. A., candidate of technical sciences, and OSHCHURKOV, P. V., engineer, Leningrad Economic Planning Department of "Elektrosila" Association

[Abstract] Testing of large turbogenerators at the producer's plant under full excitation but with a bifilar connection of rotor (field) coils, according to the General Electric procedure, has been adapted to 1000 MW - 1500 rpm and 1200 MW - 3000 rpm turbogenerators. Such tests are more reliable than the standard short tests under no load without excitation, under no load with nominal stator voltage, and under steady 3- $\phi$  short circuit with nominal stator current. Bifilar-opposing connection of field coils, by means of special jumpers in the end winding on the slipring side, suppresses the fundamental harmonic of the magnetizing force and lowers the short-circuit stator current or the open-circuit stator voltage under full excitation. Complete bifilarity and various schemes of partial bifilarity are feasible, each producing an mmf with a specific harmonic content and each being desirable for specific test conditions. In the case of 1200 MW 2-pole and 1000 MW 4-pole turbogenerators, a bifilar connection was made to change the rotor winding factor from the normal 0.838 to 0.1806 so that short-circuit stator current under full excitation would decrease to 0.295 p.u. (tested 0.286 p.u.) and 0.326 p.u. (tested 0.355 p.u.), respectively. After the factory test, all jumpers are removed for normal operation of the turbogenerator at the user's plant. Figures 5; tables 2; references: 2 Western (1 in Russian translation).  
[109-2415]

SUPERSONIC FLOW ABOUT CONE WITH INJECTION OF GAS THROUGH ITS SURFACE  
DESCRIBED BY POWER LAW

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE  
I TEKHNICHESKIYE NAUKI in Russian No 8, Aug 84  
(manuscript received 6 May 83) pp 31-35

ANTONOV, A. M. and ZAKREVSKIY, V. A., Institute of Civil Aviation Engineers,  
Kiev

[Abstract] The influence of intensive mass transfer on the supersonic flow of gas about a cone of finite length is investigated. The mathematical model describing the interaction of the primary flow and the transverse flow formed by injection is the boundary problem for a system of equations presented in the text with boundary conditions on the cone and on the contact discontinuity. It is found that the contact surface is nonrectilinear when the injected gas is described by a power law and that the thickness of the layer coming in contact with the cone increases as the intensity of the injection becomes higher. The distribution of the pressure coefficient along a finite cone is calculated as a function of the parameter  $s$  associated with the injection flow rate, and the Mach number of the oncoming stream. It is found that the pressure coefficient drops off along the generatrix of a cone for all velocities of injection and oncoming stream when the injection is distributed. As the injection intensity increases, the pressure coefficient on the surface increases. References: 5 Russian.

[120-6900]

DEVELOPMENT OF ELECTROHYDRAULIC SYSTEMS FOR REGULATION OF LMZ STEAM  
TURBINES BASED ON MICROPROCESSOR TECHNOLOGY

Moscow TEPLOENERGETIKA in Russian No 7, Jul 85, pp 12-16

MALYEV, V. V., Engineer, FRAGIN, M. S. AND MELNIKOV, V. S., Candidates of  
Technical Sciences, CHUGUNNIKOV, YU. V. AND KOLOBRODOV, N. V., Engineers,  
Leningrad Metallurgical Plant, All-Union Institute of Electric Power

[Abstract] The automation and regulation of steam turbines requires significantly increased complexity of the equipment and of operating conditions. The best solution to the problem is to use a limited number of standard devices to automate entire power units including boilers, turbines, generators, and auxiliary equipment. The electric section of the regulation system should therefore consist of primarily functions which are difficult to automate using available standard equipment due to the specific requirements placed on the automatic regulation systems of turbines, such as high speed and great reliability. This article describes a microprocessor-based electrical section for the regulation system of LMZ steam turbines.



The control system automatically supervises system start-up and run-up of the turbine. The microprocessor system contains 32 K RAM and 32 K ROM, a 48-line parallel interface, vectored interrupt controller and timer. The software also includes monitor, input-output, control action formation, switching factor checking, warmup monitoring and diagnostic programs. Figures 4; references: 6 Russian.  
[325-6900]

UDC 621.165.62-5

**KHARKOV TURBINE PLANT SYSTEM FOR CONTROL OF HIGH-POWER TURBINES FOR NUCLEAR POWER PLANTS**

Moscow TEPLOENERGETIKA in Russian, No 7, Jul 85, pp 17-20

OSIPENKO, V. D., ROZHANSKIY, V. Ye ., Engineers, and ROKHLENKO, V. YU.,  
Candidate of Technical Sciences, Kharkov Turbine Plant

[Abstract] The 750 and 1000 MW turbines manufactured at the Kharkov turbine plant are equipped with a standardized control and safety system which includes two methods of controlling regulating valves: electrohydraulic and purely hydraulic. The electrohydraulic system is the main control system and directs all startup, operating and emergency control conditions. The hydraulic system is a back-up system, allowing direct operator control and ensuring turbine safety under emergency conditions in case of a failure of the electrohydraulic system. This article describes the systems in general terms, including the interaction of the electrohydraulic and hydraulic systems and the turbine safety system. The schematic of the control system of a high-power turbine is presented. The method of controlling regulating valves and ensuring oil supply to the system for operation of the hydraulic devices are described. High-power turbine control systems are planned considering the experience accumulated by the plant, the demands of nuclear power plants and systems and the possibility of using modern electronic devices. The control system ensures high reliability, control flexibility, high-speed operation and maintenance of constant functioning of the system. Figures 1; references: 2 Russian.  
[325-6900]

## LINEAR VARIABILITY CHARACTERISTICS OF MOIST STEAM NUCLEAR POWER PLANT TURBINES

Moscow TEPLOENERGETIKA in Russian No 7, Jul 85, pp 21-25 .

KIRILLOV, V. B., Engineer, LEYZEROVICH, A. SH., Candidate of Technical Sciences, All-Union Institute of Heat Engineering

[Abstract] Nuclear power plants must be used to cover the variable portion of the power production load in the European USSR. This requires greatly reducing the power output or even shutting down the nuclear power plant turbines during slack times such as holidays. Operation of power plant turbines with widely varied loads requires that the maneuverability characteristics of the devices be known, including permissible load run-up or shedding rates and ranges of permissible loads. This article presents a method of estimating these characteristics based on temperature and heat stress states on the major structural elements under characteristic transient operating conditions. Mathematical modeling was combined with experimental testing to develop the most accurate estimates of these characteristics. It is found that the calculated maneuverability characteristics meet the technical requirements of power systems, load run-up times being characteristically 1:40-3:00 hours for turbines started cold, 35 minutes to 1:15 hours for turbines tested hot. The permissible range of load changes is at least  $\pm 50\%$  of steady-state loads. The improvement in the quality of insulation of the high-pressure section can improve the maneuverability of most types of nuclear power plant turbines. Figures 3; references: 11 Russian. [325-6900]

## CALCULATION OF AXIAL ELONGATION OF STEAM TURBINE ROTOR UNDER TRANSIENT CONDITIONS

Moscow TEPLOENERGETIKA in Russian No 7, Jul 85 pp 33-35

PLOTKIN, YE. R., Candidate of Technical Sciences, ZNIGER, M. N., Engineer, All-Union Institute of Heat Engineering

[Abstract] An important step in increasing the maneuverability of steam turbines is to increase the accuracy of calculation methods of determining the absolute and relative elongation of rotors under transient conditions as during start-up, shutdown and sudden changes in load, all of which involve significant changes in the temperature of the steam flowing through a turbine. This article discusses a method of calculating the axial elongation of the steam turbine rotor assuming axisymmetrical temperature fields of the rotor. Previously published equations yield excessive estimates of the rotor link variation under such conditions. The axial elongation of a nonuniformly heated rotor can be calculated on the basis of the mean shaft

temperature, excluding the turbine wheels, considering the additional radial effect of the wheels on the shaft, which is determined by the difference in mean temperatures of the shaft and wheels in each stage. Making the transition from calculation based on mean rotor temperature to separate consideration of the influence of shaft temperature and wheel temperature can significantly increase the accuracy of estimation of absolute and relative elongations of one-piece rotors as they are heated or cooled. Figures 3; references: 9 Russian.  
[325-6900]

UDC 621.165-546.001.5

#### DYNAMICS OF POWER TURBINE REGULATION SYSTEMS IN RESPONSE TO RANDOM PERTURBATIONS

Moscow TEPLOENERGETIKA in Russian, No 7, Jul 85 pp 39-41

KALASHNIKOV, A. A., Candidate of Technical Sciences, Moscow Institute of Power Engineer

[Abstract] The deterministic approach is the most widely used at the present to study turbine regulation systems, allowing selection of the structure and parameters on the basis of speed and stability requirements. However, only consideration of the range of the random nature of the changes in regulated parameters and controlling actions, as well as various types of noise and of the random nature of changes in the process of operation of gain factors, time constants, operating levels and other adjustment parameters, can produce accurate results in studies of the dynamics of power turbine regulation systems. Analytic studies of turbine control systems with random deviations in line frequency are used to determine the quantitative values of control quality and reliability characteristics under long-term operating conditions. Analytic studies were performed in this work including direct leveling of the random change process of dependent variables to ensure that characteristics will agree with experimentally determined values. Figures 5; references 13: 10 Russian, 3 Western.  
[325-6900]

UDC: 621.165

#### EXPERIMENTAL STUDY OF MODEL LOW-PRESSURE CYLINDERS FOR LOW-SPEED AND HIGH-SPEED 1,000 MW TURBINE UNITS

Moscow ENERGOMASHINOSTROYENIYE in Russian No 3, Mar 85, pp 4-7

SIMDYANOV, Ye. V., ZHURAVLEV, N. M. and GOLOVKIN, B. A., Engineers

[Abstract] Experiments comparing 1,500 and 3,000 rpm 1,000 MW turbine units indicated approximately equal efficiency of both types. The characteristics

of the last low-pressure stages were analyzed by calculation methods, comparing two models with steel and titanium vanes in three versions each. The major purpose of the studies was to determine the actual economy of the model segments and of the entire final stages of the turbines under actual operating conditions. Aerodynamic and vibration studies of model final stages showed that economical and reliable stages have been produced, capable of simultaneous use. The areas of most effective use of each specific version were determined. Figures 3; references: 4 Russian.  
[250-6508]

/9835

UDC: 531.383

SOME DISTINGUISHING FEATURES OF SINGLE-ROTOR CORRECTABLE GYRO COMPASSES

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 28 May 82) pp 63-64

CHICHINADZE, M. V.

[Abstract] Single-rotor correctable gyro compasses are compared with pendulum single-rotor compasses. The reduction of the error of the gyro compass during maneuvering by satisfying certain conditions in selecting the parameters of the device is investigated. It is found that the creation of correction moments on the basis of velocity, latitude and heading information produced by the gyro compass makes the guiding moment of the compass depend upon the northern component of the velocity of the vessel.

References: 7 Russian.

[49-6900]

/9835

## HIGH-ENERGY DEVICES, OPTICS AND PHOTOGRAPHY

### HIGH-ENERGY PARTICLES FROM SPACE STUDIED WITH X-RAY FILM

Moscow SOTSIALISTICHESKAYA INDUSTRIYA in Russian 21 Nov 85 p 4

[Article by K. Borodino]

[Text] Using a unit for catching high-energy particles from space in an experiment called "Pamir", scientists have obtained new data on interactions between these particles and nuclei of atoms of matter.

According to a hypothesis of physicists, electromagnetic fields operating in space and in supernova stars which flare up from time to time accelerate particles to energies which are hundreds of thousands or even millions of times as high as those which can be obtained on Earth.

Something resembling a layer cake with layers of lead and a special x-ray film in lightproof and waterproof packages was set up on a level area at an elevation of almost 5,000 meters in the Pamir Mountains. This 'cake' covers an area of almost 1,000 square meters. A single x-ray film takes up about a hectare. Particles enter the x-ray emulsion chamber and form spots on the film. The particles' energy and the character of their interaction with nuclei of atoms of matter can be judged on the basis of these spots.

Taking part in the experiment are several institutes of the USSR Academy of Sciences, as well as institutes of the Georgian, Kazakh, Tadzhik and Uzbek academies of sciences. Physicists of socialist countries and Japan are cooperating with the Soviet scientists. The Japanese scientists, incidentally, are conducting similar studies on the slopes of the famous volcano Fujiyama.

FTD/SNAP/9835

CSO: 1861/26

TRANSIENT SCATTERING OF PLANE ACOUSTIC PRESSURE WAVE BY PIECEWISE-HOMOGENEOUS PLATE

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNIЧЕСKIYE NAUKI in Russian No 11, Nov 84  
(manuscript received 12 Dec 83) pp 25-29

GALAZYUK, V. A., Lvov State University

[Abstract] Transient scattering of a plane acoustic pressure wave by an elastic piecewise-homogeneous plate is an initial-value problem for intricate mixed boundary conditions. In the case of an infinitely large plate with a perfectly rigid straight or annular inclusion of uniform width and thickness, this problem is reducible, by the apparatus of Chebyshe-Laguerre polynomials, to a sequence of Fredholm integral equations of the second kind with a regular kernel. It is solved here for a plane pulse wave impinging on an infinitely long perfectly rigid inclusion of finite width which constitutes the boundary of an acoustic half-space and for a plane continuous wave impinging on an annular perfectly rigid inclusion of finite uniform width. In both cases the Chebyshev-Laguerre integral transformation yields a sequence of ordinary differential equations. Assuming that the motion of the plate follows the classical theory of flexure, the solution to the problem will depend on only two dimensionless parameters: relative half-width of the inclusion and acoustoelastic modulus of the plate. Article was presented by Academician Ya. S. Podstrigach, UkSSR Academy of Sciences.

References 5: 4 Russian, 1 Western.

[128-2415]

## SOLUTION TO PROBLEM OF TRANSIENT DIFFRACTION OF ACOUSTIC WAVES BY INFINITELY LONG OPEN SHELLS

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNIЧЕСKIYE NAUKI in Russian No 11, Nov 84  
(manuscript received 15 Dec 83) pp 33-35

DYKHTA, V. V., Electrohydraulic Design-Engineering Office, UkSSR Academy of Sciences, Nikolayev

[Abstract] Special methods are required for solving problems of transient diffraction of acoustic waves by open shells, to ensure that the inverse transformation will restore the original uniquely where exact inverse Fourier transformation will not necessarily succeed. A method has been proposed for this applicable to open shells of arbitrary shape but finite dimensions (V. V. Dykhta, DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNIЧЕСKIYE NAUKI No 1, Jan 83). Here this method is extended to shells with infinitely large "inside" cavity such as, for instance, infinitely long cylinders with cylindrical gaps or with holes. The method is demonstrated on an undeformable infinitesimally thin acoustically soft or stiff shell of this class in a boundless initially quiescent acoustic medium. Solution of the corresponding boundary-value problem involves a Laplace transformation of the wave equation for sought velocity potentials. The boundary conditions in an orthogonal curvilinear system of coordinates are supplemented with asymptotic conditions and conditions "at the edge" so that the unknown variables can be sought in the form of integro-discrete series expansions in eigenfunctions of corresponding Sturm-Liouville problems for the case  $S_0 \equiv S$  ( $S_0$ - median surface of open shell,  $S$ - closed surface). Coefficients of the expansion, for a soft shell or for a stiff shell, respectively, yield an exact solution to the problem. Discretization of the eigenvalue spectrum corresponds to a shell of finite dimensions, which confirms the universality of this method. Article was presented by Academician Ya. S. Podstrigach, UkSSR Academy of Sciences). References: 4 Russian.  
[128-2415]



## HYDRODYNAMIC CHARACTERISTICS OF VIBRATING POLYPLANES

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNIЧЕСKIYE NAUKI in Russian No 11, Nov 84  
(manuscript received 19 Jul 84) pp 46-48

SHCHIPTSOV, A. A., Institute of Hydromechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Vibrations of a polyplane in an ideal incompressible fluid are analyzed by the method of discrete vortices. The problem is formulated in a Cartesian system of coordinates for an even number of foils and for an odd number of foils, each foil being replaced with the resultant  $\Gamma^r$  of free and attached vortex components and a linear free vortex trail  $\delta^s$  which was assumed to form behind the trailing edge at each discrete instant of time. The conditions of impermeability and of circulation conservation yield a closed system of  $(N + 1)M$  algebraic equations with  $N \cdot M + M = (N + 1)M$  unknowns ( $M$  - number of foils,  $N$  - number vortices equivalent to a foil) linear with respect to  $\Gamma^r$  and  $\delta^s$ . This system can be reduced, on the basis of symmetry, to  $1/2(N + 1)M$  equations for even numbers of foils or to  $1/2(N + 1)(M + 1)$  equations for odd numbers of foils. Solution of this system of equations yields the dependence of the thrust coefficient on the kinematic characteristics and on the number of foils as well as on the pitch-to-chord ratio of the foil array. Calculations made for translational-rotational vibrations of  $M = 1, 2, 3, 4$  foils in an array with a pitch-to-chord ratio

$$0 < \frac{t}{b} \leq 2 \text{ moving at a}$$

dimensionless velocity ranging from 2.5 to 4 indicate the suitability of polyplanes for propulsion. (Article was presented by Academician V. V. Pilipenko, UkSSR Academy of Sciences). Figures 5; references: 4 Russian.  
[128-2415]

## DIRECTIVITY OF SOUND RADIATION FROM COMPENSATED ARCUATE ARRAY OF INFINITELY LONG ELLIPTIC CYLINDRICAL RADIATORS

Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 30, No 3, May-Jun 84  
(manuscript received 20 Sep 82) pp 364-367

SILETSKIY, S. M.

[Abstract] Radiation of sound from an array of infinitely long elliptic cylinders into a boundless homogeneous and isotropic medium is analyzed, assuming that the longitudinal axes of these cylinders are spaced along a circular arc and their elliptic normal cross-sections, generally of arbitrary dimensions and orientations, do not touch one another. The

problem reduces to the two-dimensional Helmholtz wave equation which, with appropriate boundary conditions at the surface of each cylinder, is solved for the amplitude of the velocity potential in the resultant acoustic field. A numerical solution has been obtained for the special case of five identical cylinders equidistant along an open arc with the major axes of their normal cross sections tangent to that arc, radiating synphasally in the direction normal to the arc through its center with a constant-amplitude distribution of vibration velocity over their active surfaces. A comparison of the results for such an array in open space or with an acoustically soft shield subtending a  $180^\circ$  angle indicates that interaction of the radiators with a shield behind will shrink the back lobes of the radiation pattern and slightly shift the latter toward the center of the arc. The authors thanks I. L. Oboznenko for interest in the study and discussion of the results. Figures 3; references: 5 Russian. [288-2415]

UDC 534.833

#### SOUND ISOLATION IN WIDE CYLINDRICAL TUBE WITH ANNULAR GROOVES IN WALL

Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 30, No 3, May-Jun 84  
(manuscript received 21 Dec 82) pp 395-396

KUZNETSOV, P. V. and NOSKO, G. S., Voroshilovgrad Institute of Machine Design

[Abstract] The acoustic field in a cylindrical tube representing a turbomachine, with a number of equidistant identical annular grooves  $m$  approximately equal to the number of blades  $N$ , was analyzed as a field with  $m$ -th order symmetry and with the solution to the wave equation being a harmonic function of time as for a multimode waveguide. The already established feasibility of attenuating the  $m_0$ -mode in a waveguide by means of an array of axisymmetric resonators was experimentally adopted for isolating acoustic noise in a turbomachine. The experimental data on the bandwidth and the attenuation coefficient agree satisfactorily with the predicted performance of resonators optimally designed for given tube volume and groove frequency characteristics. Figures 2; references 5: 4 Russian, 1 ISO. [288-2415]

# HYDRODYNAMIC INTERACTION OF TWO SPHERICAL PARTICLES CAUSED BY SOUND WAVE PROPAGATING ALONG CENTER-TO-CENTER LINE

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 20, No 9, Sep 84  
(manuscript received 15 Jul 83) pp 111-116

ZHUK, A. P., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Forces in a two-particle system in a fluid with an acoustic field are calculated, specifically for two identical spherical particles some distance apart in a boundless ideal fluid with a plane sound wave propagating along the center-to-center line. One problem here is diffraction of sound by the downstream particle, formulated as the corresponding wave equation in the potential of the reflected wave field for a given potential of the incident wave field. This problem is solved by the method of separation of variables in spherical coordinates and subsequent reduction, assuming that the particles move in accordance with Newton's Second Law. The force problem is solved for  $kd \gg 1$  ( $K = \omega/\alpha$ ,  $\omega$ -frequency of sound wave,  $\alpha$ - acoustic velocity in fluid,  $2d$ -initial center-to-center distance between free spheres), which permits the use of coefficients of spherical functions in series expansions of the wave field potentials in the preceding problem. The solution yields the resultant force on the downstream particle as consisting of two components, the force of sound radiation pressure and the force of hydrodynamic interaction. The latter is produced by the diffraction field of this particle, without reaction of this particle on the upstream one. The expressions simplify appreciably for long waves  $\alpha = k\alpha \ll 1$ , because higher-order terms in  $\alpha$  can be discarded as  $\alpha \rightarrow 0$ . The relations for  $kd \rightarrow \infty$  are identical to those for a single spherical particle in a fluid with an acoustic field. The example of a hydrodynamic interaction force

$$F \approx 2\pi\rho_0\alpha^6 \frac{\sin(4kd)}{2kd} \frac{5 - 4\eta}{9(2 + \eta)} \text{ in water } (\rho_0 = 1000 \text{ kg/m}^3,$$

$\eta$ - ratio of particle density to water density) is subject to change of magnitude and reversal of direction as either the frequency of sound or the ratio of densities changes. Figures 2; references 14: 11 Russian, 3 Western.  
[52-2415]

ACTION OF NONAXISYMMETRIC NORMAL LOAD ALONG SURFACE OF ELASTIC SHELL  
INTERACTING WITH FLUID

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 20, No 9, Sep 84  
(manuscript received 29 Sep 82) pp 58-64

POZHUYEV, V. I., Zaporozhye Industrial Institute

[Abstract] A coaxial infinitely long pair of a cylindrical shell around a solid cylinder is considered with an ideal compressible fluid filling the channel and interacting with the outer cylinder. The latter is under normal pressure arbitrarily distributed in space, over the length and around the circumference, but constant in time. The problem of a load moving on the surface parallel to axis is solved by means of integral transformation with respect to the axial coordinate and Fourier series expansion with respect to the angular coordinate. The velocity of the load is assumed to be constant, but of arbitrary magnitude relative to the acoustic velocity in the fluid. Nonaxisymmetric vibrations of the shell are described by equations of dynamics for a Timoshenko shell, with terms added which represent radial damping and reaction of the fluid, while motion of the fluid is described by the wave equation. These equations are solved by integration for boundary conditions of an impermeable inside shell surface and a rigid solid cylinder. The analytical solution of the problem is shown for a self-balancing array of loads discrete concentrated around the shell and continuous exponentially decreasing along the shell. It has been solved numerically for a steel shell and incompressible fluid (water) flowing through the channel at velocities ranging from subsonic to supersonic ones up to  $M=2$ . Figures 3; tables 3; references 13: 12 Russian, 1 Western.  
[52-2415]

/9835

UDC: 531.53

CONTROL OF OSCILLATIONS OF PENDULUM SYSTEM WITH BIFILAR SUSPENSION

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 18 Jan 82) pp 14-21

NGUEN CHYONG, Hanoi

[Abstract] This study describes the movement of a pendulum in the vertical plane such that a weight is suspended by two identical filaments comprising a bifilar suspension connection to a trolley which moves horizontally. The movement of the trolley is controlled by the speed developed by motors having restricted speeds. Two problems are stated and solved: a movement problem, in which a control must be found which satisfies the stated restrictions and moves the system from the resting state over a given distance with damping of the oscillations, and an acceleration problem, in which a control must be found which satisfies the same restrictions and moves the system from the resting state to a state of reciprocating motion with damping of oscillations. A relay control with three constant-velocity sections is constructed. The findings are of interest in the investigation of optimum operating conditions for loading and unloading mechanisms which carry oscillating loads on bifilar suspensions. References: 3 Russian.  
[49-6900]

UDC: 531.53

STABILITY OF SCHULER PENDULUM WITH SUSPENSION POINT MOVING ALONG PARALLEL AT CONSTANT VELOCITY

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 10 Nov 81) pp 22-25

AGAFONOV, S. A.

[Abstract] The movement of a Schuler pendulum is investigated for the case of the suspension point moving along the parallel at a constant velocity. The problem of stability is solved with the help of Arnold-Moser theorem: if the Hamilton function for perturbed motion is such that no resonance

relationships are satisfied between the frequencies of the linear system, the equilibrium is stable according to Lyapunov. A numerical problem is calculated as an example; the results are formulated as a theorem. References:

6 Russian.

[49-6900]

UDC: 531.53

#### PROBABILITY CHARACTERISTICS OF STOCHASTIC OSCILLATIONS OF ADJUSTABLE PENDULUM

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 18 Jun 82) pp 26-31

LANDA, P. S. and STRATONOVICH, R. L.

[Abstract] It is demonstrated that stochastic self-sustained oscillation of an adjustable pendulum can often be investigated without solving the corresponding nonlinear equations analytically if the statistical characteristics of the process; such as the steady-state probability distribution, are known. Such a distribution has been shown to exist, and to be independent of the initial distribution, for a certain class of dynamic systems which can be described by an exponentially unstable unidimensional point mapping. Such a distribution is shown to exist for other systems which generate stochastic self-sustained oscillations. References 12: 11 Russian, 1 Western.

[49-6900]

UDC: 531.38

#### ROTATION OF BODY IN MAGNETIC FIELD

Moscow MEKHANIKA TVERDOGO TELA in Russian No 4, Jul-Aug 84  
(manuscript received 5 Mar 83) pp 32-34

SANSONOV, V. A.

[Abstract] The problem of the rotation of a dynamically symmetrical body with a stationary point in a unidimensional magnetic field and subjected to forces generated by the Barnett-London effect is investigated. The motion is interpreted in the space  $\theta, u, v$  by constructing a set of stationary movements of the body such that  $\theta(t) = \theta(t_0) = \text{const}$  ( $0 < \theta < \pi$ ). The steady-state movements of this type are regular precessions or permanent revolutions. References: 6 Russian.

[49-6900]

## GENERAL SOLUTION OF SPATIAL PROBLEM OF ELASTICITY THEORY FOR MULTILAYER ORTHOTROPIC CYLINDRICAL SHELL

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNICHESKIYE NAUKI in Russian No 8, Aug 84 (manuscript received 5 Mar 84) pp 46-48

KOSMODAMIANSKIY, A. S., Corresponding Member, Ukrainian SSR Academy of Sciences, and GALICH, V. A., Donetsk State University

[Abstract] The separation of variables method is employed to find an analytical solution to the problem of the stress-strain state of an m-layer thick cylindrical shell made of cylindrically orthotropic materials. The curvilinear part of the lateral surface of the shell is assumed to be free of external forces, and the layers are in rigid contact with one another. The problem is formulated as one of finding the displacement vector  $\vec{u}_m = (u_{1m}, u_{2m}, u_{3m})$ , where m is the number of the shell layer, for the equations  $\vec{L}_{mj} \vec{u}_m = 0$  ( $j = 1, 3$ ) under boundary conditions specified in the text. The case of normal pressure inside the shell is analyzed as an example. References: 2 Russian. [120-6900]

## OSCILLATION OF ELASTIC SYSTEM WITH HYSTERESIS SCATTERING OF ENERGY

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNICHESKIYE NAUKI in Russian No 8, Aug 84 (manuscript received 9 Jun 83) pp 53-56

PAVLOVSKIY, M. A. and RYZHKOV, L. M., Kiev Polytechnical Institute.

[Abstract] The hysteresis scattering of energy in elastic systems is investigated. It is shown that not all of the equations for the hysteresis loop describe the phenomenon of unstable amplitudes of certain oscillations. A functional is derived that makes it possible to describe oscillations with unstable amplitudes occurring during hysteresis scattering of energy. The finding is confirmed by the presence of sections with ambiguous amplitudes in amplitude resonance curves for  $n \geq 4$ . References: 5 Russian. [120-6900]

# NONLINEAR VIBRATIONS OF FLEXIBLE CIRCULAR PLATES UNDER BENDING AND TENSION OR COMPRESSION LOADS

Kiev DOKLADY AKADEMII NAUK UKRAINSKOY SSR, SERIYA A: FIZIKO-MATEMATICHESKIYE I TEKHNIЧЕСKIYE NAUKI in Russian No 11, Nov 84  
(manuscript received 21 May 84) pp 36-39

KOSMODAMIANSKIY, A. S., corresponding member, UkSSR Academy of Sciences, and  
TATARINOVA, O. P., Donetsk State University

[Abstract] Nonlinear flexural vibrations of a flexible circular plate are analyzed, its edge being either movable on a hinge or movable in a clamp under a uniformly distributed radial tension or compression force which varies harmonically in time. The deflection  $w(r,t)$  and the necessarily finite radial membrane force  $N_r(r,t)$ , both functions of the radius and of time, are determined from the corresponding system of nonlinear differential equations for boundary conditions

$$w=0, \frac{\partial^2 w}{\partial r^2} + \frac{\mu}{r} \frac{\partial w}{\partial r} = 0, N_r = -N \text{ at a hinged edge or}$$

$$w=0, \frac{\partial w}{\partial r} = 0, N_r = -N \text{ at a clamped edge } (\mu - \text{Poisson ratio of the plate material}).$$

The problem, formulated in accordance with classical linear theory, is solved by the Bubnov-Galerkin method. The result reveals that the period of nonlinear free vibrations depends on their amplitude. Nonlinear induced vibrations, in the binomial approximation with a fundamental component and a third harmonic only, are characterized by an interdependence of amplitude and frequency (period). References 3: 1 Russian, 1 Western (in Russian translation), 1 Chinese (in Russian translation).

[128-2415]

UDC: 534.012:539.67

# LONGITUDINAL WAVES IN VISCOELASTIC ROD WITH DRY FRICTION ON BOUNDARY

Moscow VESTNIK MOSKOVSKOGO UNIVERSITETA, SERIYA I: MATEMATIKA, MEKHANIKA in Russian No 5, Sep-Oct 84 (manuscript received 12 Aug 82)  
pp 53-57

SAKHAROVA, A. S.

[Abstract] A semiinfinite viscoelastic rod with a constant cross-section is examined whose lateral surface interacts with its environment in accordance with Coulomb's law of dry friction. A longitudinal shock is applied to the end  $x = 0$  with a constant velocity. The friction force occurring on the lateral surface is interpreted as a mass force uniformly distributed over the cross-section. The procedure derived is employed to solve the problem of a viscoelastic rod with friction on the lateral



surface proportional to the relative rate of movement of the particles of the rod and the surrounding medium. References: 5 Russian.  
[73-6900]

UDC 534.833

DYNAMIC EDGE EFFECT IN RIGID HOMOGENEOUS VIBRATION-ABSORBER COATING

Moscow AKUSTICHESKIY ZHURNAL in Russian Vol 30, No 3, May-Jun 84  
(manuscript received 10 Nov 82) pp 368-372

STEPANOV, V. B. and TARTAKOVSKIY, B. D., Institute of Acoustics,  
imeni N. N. Andreyev USSR Academy of Sciences

[Abstract] The dynamic edge effect in a rigid homogeneous single-layer coating of a vibration-absorber material on metal was studied experimentally and is analyzed theoretically, for the purpose of determining its frequency dependence and its manifestation at higher frequencies up to 2500 Hz. For the experiment, steel bars 0.04-0.06 m thick with a  $1.28 \times 0.04$  m<sup>2</sup> rectangular cross-section were coated on one side with 0.008-0.016 m thick layers of "Agat" thermoplastic. First the dependence of the potential strain energy in the coating on the wave dimensions of the latter was determined from the width of resonance peaks of the input admittance and from the shift of resonance frequencies of the flexural vibration modes, after the solid coatings had been split successively into 4, 8, and 16 identical segments, respectively, 0.32, 0.16, and 0.08 m long. The edge effect was then evaluated in terms of the equivalent relative contraction, namely the ratio of the change of segment length to coating thickness. The subsequent theoretical analysis of the frequency dependence is based on an approximate model, a coating of given length, width, and thickness solidly adhering to a vibrating metal bar of given thickness. The scale factor which defines the length of the edge zone is determined from the longitudinal strain and two components (longitudinal and normal) of displacement. Solution of the corresponding Lagrange equation by the variational method reveals that the edge effect is maximum when the end of a coating segment coincides with a crest of the bar deformation wave and is minimum when it coincides with a node. The edge effect is, moreover, most appreciable during quasi-static deformation of the coating, and its average magnitude decreases with increasing wave dimensions of the coating. Figures 5; references: 2 Russian.  
[288-2415]

## STABILITY OF NONCIRCULAR CYLINDRICAL SHELLS UNDER AXIAL COMPRESSION

Kiev PRIKLADNAYA MEKhanika in Russian Vol 20, No 9, Sep 84  
(manuscript received 15 Sep 83) pp 43-49

SEMENYUK, N. P., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] Stability of cylindrical shells with corrugated cross section under axial compression is analyzed exactly, on the basis of Kirchhoff-Love hypotheses with variation of the thickness metrics and according to the variational criterion  $\iint [T\delta\epsilon + M\delta\kappa - T_{11}^0(\epsilon, \delta\epsilon, + \omega\delta\omega_1 + \theta_1\delta\theta_1)] A_1 A_2 d\xi d\phi$

( $T$ - vector of forces,  $M$ - vector of moments,  $\epsilon_0$ - vector of tensile-compressive strains,  $\kappa$ - vector of flexural strains,  $T_{11}$ - subcritical compression,  $\epsilon_1 = \partial u/\partial x$ ,  $\omega_1 = \partial v/\partial x$ ,  $\theta_1 = \partial w/\partial x$ ,  $u, v, w$ - displacement components,  $x$ - axial coordinate) with Fourier series expansion of the displacement components. For illustration is considered a shell on hinge supports with a generatrix describable by the equation  $\rho = R_0(1 + \epsilon \cos N\phi)$  in a polar system of coordinates  $\rho, \phi$  ( $R_0$ - radius of smooth circular cylinder,  $\epsilon R_0$ - amplitude of corrugation,  $N$ - number of surface waves around circumference). Calculation of the critical load and the buckling mode reveals that the number of possible buckling modes increases but the order of the system of equations does not change as the number of corrugation waves increases. The procedure has been applied to shells with mean radius  $R_0 = 0.2$  m and length  $L = 0.4$  m, of a material with Young's modulus  $E = 7.2 \cdot 10^4$  MPa and Poisson's ratio  $\nu = 0.3$ , having various corrugations with amplitude

$$\epsilon = (0.1-48) \frac{t}{R} \text{ and number of waves}$$

$N = 5-48$ . The results indicate that such shells with  $N < 30$  are less stable than the circular shell with radius  $R_0$ , the shell with  $N = 7$  being least stable of all. Their buckling modes are also compared to those of the circular shell, and the classical theory is found to be applicable here too, after appropriate refinement of hypotheses and without assuming a small thickness  $t/R$ . For design purposes the results indicate that, with noncircularity or waviness of the median surface regarded as an initial imperfection, the most vulnerable to stability loss are shells with a small number of circumferential corrugation waves equal or nearly equal to multiples of the number of buckling waves of the corresponding perfect circular shell.

Figures 4; tables 1; references 6: 5 Russian, 1 Western.

[52-2415]

## OPTIMIZATION OF CYLINDRICAL SHELLS WITH VARIABLE THICKNESS FOR AXISYMMETRIC LOAD

Kiev PRIKLADNAYA MEKhanika in Russian Vol 20, No 9, Sep 84  
(manuscript received 24 May 83) pp 53-57

MEDVEDEV, N. G. and TOTSKIY, N. P., Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] The optimization of closed cylindrical shells with variable wall thickness for strength under a given axisymmetric load is formulated in accordance with the principle of virtual work. Minimum weight is selected as the optimality criterion, with the wall thickness as function of space coordinates as the control. The latter is constrained by minimum and maximum thicknesses, in addition to the strength requirement. As specific example is considered an orthotropic shell with the wall thickness a function of the axial coordinate only. All stress components are calculated from the corresponding equations of elasticity. After regularization of the displacement components, for meaningful maximization and minimization, optimum control is sought as a problem of nonlinear programming. This problem is solved approximately, with a piecewise-linear continuous control function. A numerical solution has been obtained for an isotropic cylindrical shell under a uniformly distributed external pressure. Figures 2; references: 11 Russian. [52-2415]

## SPECTRUM OF NORMAL WAVES IN HOLLOW TRANSVERSELY ISOTROPIC CYLINDER

Kiev PRIKLADNAYA MEKhanika in Russian Vol 20, No 9, Sep 84  
(manuscript received 23 Dec 82) pp 117-118

MOISEYENKO, V. A., STOROZHEV, V. I. and SHULGA, N. A., Donetsk State University and Institute of Mechanics, UkSSR Academy of Sciences, Kiev

[Abstract] The spectrum of axisymmetric normal waves in a hollow transversely isotropic cylinder is calculated from the corresponding system of two differential equations of motion. The amplitude components of the stress tensor are related to the amplitude components of the displacement vector through Hooke's law, with both the inside and outside surfaces of the cylinder assumed to be stress-free. Equating the characteristic determinant to zero yields the dispersion equation, and solution of the latter yields the relation between the dimensionless wave number and the frequency parameter for given ratio of outside radius to inside radius and the given set of five elasticity parameters (three stiffness moduli and two shear moduli). A numerical analysis for a beryllium cylinder has yielded dispersion curves characterizing modes which converge but do not intersect. Figures 1; references 4: 3 Russian, 1 Western. [52-2415]

## NATURAL VIBRATIONS OF SPHERICAL SHELLS REINFORCED WITH MERIDIONAL HOOPS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 20, No 9, Sep 84  
(manuscript received 28 Dec 83) pp 119-121

REVUTSKIY, V. N., Institute of Mechanics, UkSSR Academy of Sciences

[Abstract] The effect of meridional reinforcing hoops on the natural frequencies of a spherical shell rigidly clamped around one parallel is analyzed on the basis of the Hamilton-Ostrogradskiy principle of stationary ("least") action. The corresponding system of differential equations of motion is formulated in spherical coordinates, with displacements expanded into series in associated Legendre polynomials and their derivatives. Application of the Bubnov-Galerkin method reduces this system of differential equations to two independent infinite homogeneous algebraic ones in unknown mode coefficients. The natural frequencies are calculated approximately by solving the algebraic eigenvalue problem, put in matrix form. The lowest-order natural frequencies have been calculated for a thin spherical shell (ratio of radius to thickness  $R/h = 400$ ) with two orthogonal hoops made of the same material as the sheath. The results reveal that increasing the flexural stiffness of hoops raises the natural frequencies slightly, while increasing their cross section drops the natural frequencies appreciably. When the hoops are located at nodes of surface waves, then their effect is negligible and the shell vibrates as if it were smooth. Figures 3; references 3: 2 Russian, 1 Western (in Russian translation).  
[52-2415]

## THEORY OF NONLINEARLY ELASTIC MULTILAYER SHELLS WITH TRANSVERSE SHEAR STRAIN

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 20, No 9, Sep 84  
(manuscript received 4 Jul 83) pp 124-127

VERIZHENKO, V. Ye., Kiev Institute of Structural Engineering

[Abstract] The relations of stressed-strained state for isotropic multilayer shells according to the classical model on the basis of the Kirchhoff-Love hypothesis are formulated with separation of linear and nonlinear components of transverse shear. The resulting exact relation for tangential components of the displacement vector is then used as hypothesis for constructing a physically nonlinear nonclassical theory, which is more adequate for design purposes than conventional classical and nonclassical approximate two-dimensional theories in that it takes into account the nonlinear elastic behavior of materials as well as transverse shear in multilayer shells. Figures 1; references: 9 Russian.  
[52-2415]

## ANALYSIS OF COMPLEX-MOTION KINEMATICS OF BODIES BY MATRIX METHODS

Kiev PRIKLADNAYA MEKHANIKA in Russian Vol 20, No 9, Sep 84  
(manuscript received 5 Jul 82) pp 130-131

KONOPLEV, V. A., Leningrad Institute of Ship Building

[Abstract] Relations describing the kinematics of absolute motion of bodies are converted from vector form to matrix form so as to extend the known relations (ANALYTICAL MECHANICS by A. I. Lurye, Fizmatgiz, 1961) for plain motion to any number of relative motions. The resulting expressions for displacements, velocities, and accelerations of any point of a body are compact and convenient for computer-aided calculations. A typical example is the extremely simple formulation devised at the Moscow Higher Technical School imeni N. E. Bauman for analyzing the kinematics of its robot with automatic manipulator. References: 4 Russian.  
[52-2415]

UDC: 539.3

## CONSIDERATION OF PHYSICAL NONLINEARITY AND CHANGES IN GEOMETRIC PARAMETERS IN CYLINDRICAL SHELL MOTION CONTROLS

Baku DOKLADY AKADEMII NAUK AZERBAYDZHANSKOY SSR in Russian Vol 41, No 3, Mar 85 (manuscript received 19 Apr 84) pp 20-23

KIYASBEYLI, T. N., All-Union Scientific Research and Planning Institute for the Gas Industry

[Abstract] A study is made of a refined version of equations of motion of cylindrical shells based on the Kirchhoff-Love hypothesis considering physical nonlinearity of the material and changes in geometric parameters from layer to layer through the thickness of the shell. It is assumed that the yield point of the material is independent of mean stress and is determined only by the intensity of shear stress. The differential equations of motion obtained for physically nonlinear cylindrical shells coincide with equations obtained earlier using a linear elasticity rule. References: 5 Russian.  
[238-6508]

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